GEOLOGICAL SURVEY OF NEW SOUTH WALES.

THE

# MINERAL RESOURCES

OF

# NEW SOUTH WALES.

EDWARD F. PITTMAN,

Government Geologist.

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*From a photograph by E. F. Pittman.*

GROUP OF GOLD CRYSTALS

In the possession of W. Monie, Esquire, jun., Sydney.

Found in a vugh in a lode, at a depth of twenty feet from the surface, at Upper Bingara, N.S.W. Weight of large piece, 10·78 ounces; weight of small piece, 1·02 ounce. The two pieces were originally joined together. (Slightly less than natural size.)

GEOLOGICAL SURVEY OF NEW SOUTH WALES.

THE

# MINERAL RESOURCES

OF

# NEW SOUTH WALES.

BY

EDWARD F. PITTMAN,

*Associate of the Royal School of Mines, London;*
*Member of the Institution of Mining and Metallurgy;*
*Government Geologist of New South Wales;*
*Lecturer in Mining at the Sydney University.*

ISSUED BY DIRECTION OF

THE HONORABLE J. L. FEGAN, M.P.,

MINISTER FOR MINES.

SYDNEY: WILLIAM APPLEGATE GULLICK, GOVERNMENT PRINTER.

1901.

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## CORRIGENDA.

Page 86, line 10.—*For* late Mr. C. Watt *read* Mr. W. A. Dixon.
„ 99, „ 2.— „ Black *read* Block.
„ 111, „ 21.— „ slopes „ stopes.
„ 144, „ 30.— „ 1898 „ 1899.
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„ 286, „ 13.— „ f.o.b. „ c.f.i.
„ 336, „ 3.— „ Lower Coal Measures *read* Upper Coal Measures.
„ 379, „ 24.— „ subject *read* subjected.
„ 458, map opposite.—Figures for parallels of latitude on left-hand side of map are correct, on right-hand side incorrect.
„ 476, column 4.—*For* $K_3CO_3$ *read* $K_2CO_3$.

# CONTENTS.

## Part I.

## METALS AND METALLIFEROUS MINERALS.



## Part II.

## NON-METALLIFEROUS SUBSTANCES.



## SUPPLEMENT.

Geological Survey Branch, Department of Mines,
Sydney, 1st October, 1900.

Sir,

I have the honor to transmit for publication my notes on the Mineral Resources of New South Wales.

No attempt has been made to describe all the ore-deposits of the Colony; all that was possible, within the limits of such a volume as this, was to indicate the mode of occurrence of the principal *types* of deposits, and to supplement this, for the use of the prospector, by a list of the known localities of the different economic minerals. It has long been felt that some such volume was necessary, in order that an idea of the magnitude and variety of the mineral wealth of the Colony might be obtained by the public, without the labour of referring to a number of separate official publications.

In regard to the geological portion of the work, free use has been made of the writings of the late Rev. W. B. Clarke, the late Mr. C. S. Wilkinson, Professor David, Professor Liversidge, and the officers of the Geological Survey; I have also had the advantage of personally examining most of the occurrences during a term of twenty-two years' service in the Department.

The statistical information has been obtained from the Annual Reports of the Department of Mines, compiled by yourself and your predecessor, Mr. Harrie Wood.

While many errors and omissions will doubtless be noticed in these pages, it is hoped that a certain amount of useful information will also be found by the mining community.

My best thanks are due to Mr. G. W. Card for assistance in the determination of minerals and rock sections; to Mr. W. S. Dun for the identification of fossils, the correcting of proof-sheets, and the compilation of an index; to Mr. Oliver Trickett for his careful preparation of the plans and sections illustrating this book; and to Messrs. Grosse and Chambers for developing photographic negatives.

The managers of the various mines alluded to have courteously given me much valuable information.

I have the honor to be, Sir,

Your obedient servant,

EDWARD F. PITTMAN.

D. C. McLachlan, Esq.,
Under Secretary for Mines.

TO THE MEMORY

OF

MY OLD FRIEND AND CHIEF

C. S. WILKINSON, F.L.S., F.G.S.,

LATE

GEOLOGICAL SURVEYOR IN CHARGE.

# INTRODUCTORY.

When Australia was being colonised the pastoral industry was the first to be established, the suitability of the soil and climate for this purpose being recognised by the early settlers; but for a considerable time there was no market for the produce, and the times were bad. Then came the discovery of great quantities of easily-won gold, which quickly attracted a large population, and, as a natural consequence, the demand for commodities of all descriptions increased enormously; agriculture soon became a profitable industry, and of recent years it has made great progress in the Eastern and Central Divisions. But although meat, wool, cereals, and wine will always be staple products of the country, it must not be forgotten that the prosperity of Australia dates from the discovery of gold, which resulted in the building of such cities as Sydney and Melbourne. Moreover, the mining industry must, for many years to come, be one of the most important factors in maintaining and increasing our national wealth; and New South Wales, with its abundant supplies of coal, bids fair to become the principal manufacturing centre.

There are probably few countries in the world which have been endowed with such a diversity of mineral wealth in proportion to area as the Colony (or State, as it will shortly become) of New South Wales. Its area is 310,700 square miles, while its population, according to the latest estimate of the Government Statistician, is 1,361,120, or at the rate of only one person to every 146 acres. The total value of all the metals and minerals produced prior to the 31st December, 1899, was £134,064,712, while the value of the mineral production for the year 1899 was £6,157,557. It is only reasonable to expect that as the population becomes denser, and better facilities are provided, many new mineral deposits will be discovered which will add to the importance of the mining industry.

It is proposed to refer our mineral resources under two principal divisions, viz., I—Metals and Metalliferous Minerals; and II—Non-Metalliferous substances. Under the first division will be included Gold, Platinum, and the ores of Silver, Tin, Copper, Zinc, Lead, Iron, Aluminium, Cobalt, Nickel, Managanese, Antimony, Bismuth, Mercury, Chromium, Tungsten, and Molybdenum. Under the head of Non-Metalliferous substances will be considered Coal, Coke, Kerosene Shale, Graphite, Diamonds, Precious Opal, Emeralds, Turquoise, Sapphires and other Gems, Alunite, Asbestos, Diatomaceous Earth, Fireclay, Ochre, Marble, Limestone, Building Stone, etc. Descriptions will also be given of several Mineral Springs, and of the Artesian Water Supply.

As reference will be made in these pages to the geological conditions. under which the different mineral deposits occur, it may be as well to give a tabulated statement showing in chronological order all the geological formations at present known to exist in New South Wales.

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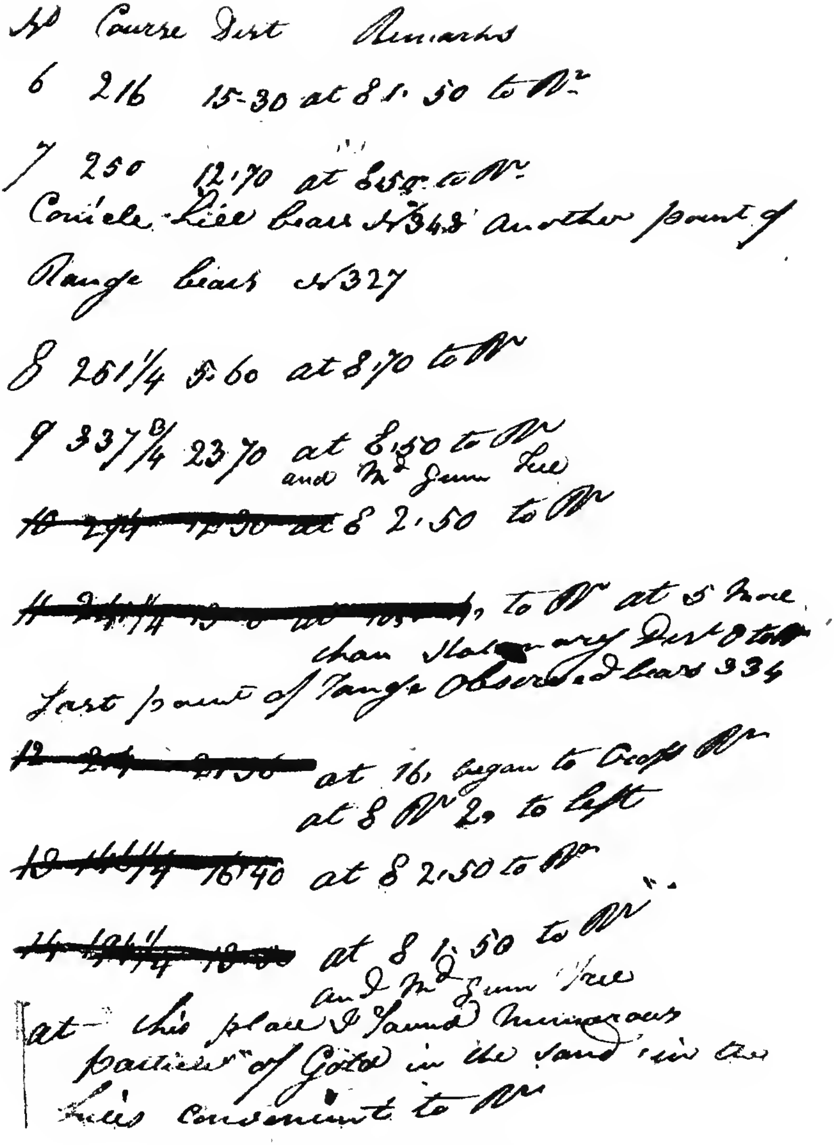
# Classification of the Sedimentary Rocks of New South Wales.

| | | | | |
|---|---|---|---|---|
| CAINOZOIC. | Post Tertiary ... | Recent. Auriferous soils, and alluvial deposits in the beds of existing rivers. | | |
| | | Pleistocene. Alluvial leads containing gold, tin, and gem-stones. | | |
| | Tertiary .. | Pliocene. Alluvial leads, frequently covered by basalt, and containing gold, tin, and gemstones. | | |
| | | Miocene. Quartzites with plant remains at Dalton, near Gunning. | | |
| | | Eocene. Marine limestones and calcareous sandstones of the Lower Darling; plant beds of the New England District. | | |
| MESOZOIC. | Cretaceous ... | Upper Cretaceous (Desert Sandstone). Contains precious opal deposits. | | |
| | | Middle Cretaceous. Auriferous alluvial leads at Mount Brown. | | |
| | | Lower Cretaceous (Rolling Downs Formation). Some of the beds are porous sandstones, and contain artesian water. | | |
| | Jurassic ... | Talbragar fish-bearing shales. | | |
| | Triassic ... | Hawkesbury series and their equiva-lants ... ... | Wianamatta shales (contain fire-clays). Hawkesbury sandstones (building stone). Narrabeen shales. | |
| | | The Ipswich Coal Measures ... | Form the base of the artesian water basin. These measures contain thin coal seams, not at present worked in New South Wales. | |
| PALÆOZOIC. | Permo-Carboniferous ... | Upper or Newcastle Coal Measures ... | | The productive coal seams of N.S.W. occur in these measures. |
| | | Dempsey Series. | | |
| | | Middle or Tomago Coal Measures ... | | |
| | | Upper Marine Series | | |
| | | Greta Coal Measures | | |
| | | Lower Marine Series. | | |
| | Carboniferous.. | Rhacopteris Beds and associated Marine Beds. Gympie claystones (of Queensland). | | All the metalliferous lodes and reefs occur in the Silurian, Devonian, and Carboniferous formations, or in such igneous rocks as granites, quartz-porphyries, felsites, and diorites. |
| | Devonian ... | Upper Devonian ... | | |
| | | Lower Devonian ... | | |
| | Silurian ... | Upper Silurian ... | | |
| | | Lower Silurian .. | | |



No Course Dist Remarks
6 216 15·30 at 81·50 to Nᵒ
7 250 12·70 at 85·0 to Nᵒ
Conical Hill bears N 348 another point of
Range bears N 327
8 261¼ 5·60 at 8·70 to Nᵒ
9 337¾ 23·70 at 8·50 to Nᵒ
and Mc Gunn tree
[redacted] at 8 2·50 to Nᵒ
[redacted], to Nᵒ at 5 more
than stationary Dist 8 to
Last point of Range observed bears 334
[redacted] at 16, began to cross Nᵒ
at 8 Nᵒ 2, to left
[redacted] 16·40 at 8 2·50 to Nᵒ
[redacted] at 8 1·50 to Nᵒ
and Mc Gunn tree
at this place I found numerous
particles of Gold in the sand in the
hills convenient to Nᵒ

*Facsimile of a page of Surveyor Mc Brien's field book, recording the discovery of gold in 1823.*

## CORRIGENDA.

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# PART I.

# Metals and Metalliferous Minerals.

## GOLD.

### History of the Discovery of Gold in Australia.

The discovery of gold was destined to have a wonderful effect in the development of Australia, and it was in the mother colony (New South Wales) that the first traces of the precious metal were recognised, and also that the first goldfields were worked, although this did not happen until many years after gold was known to exist in the soil.

**1530-36.** The *Dauphin Chart* (a map of Australia, date 1530-36), which is preserved in the British Museum, and which is believed to have been reproduced from earlier Portnguese charts, makes it appear probable that the occurrence of gold in Australia was known to the Portuguese and Spaniards more than 350 years ago, for the north-western coast of the island is named on this chart *Costa D'Ouro* (Gold Coast).

**1823.** However, the first definite record of the discovery of gold in this country is a note by Mr. James McBrien, Assistant Surveyor, in a field-book which he used while making a survey of the Fish River, between Rydal and Bathurst. This field-book is preserved in the plan-room of the Department of Lands in Sydney, and is registered as No. 204. The note is dated Febrnary 15th, 1823, and reads as follows:—"At 81 chains 50 links to river and marked gum-tree. At this place I fonnd nnmerous particles of gold in the sand in the hills convenient to river." It may be mentioned that the locality referred to by Mr. McBrien is of granite formation, and a considerable amount of gold has in recent years been won from the soil in this neighbourhood by the process known as *surfacing*.

**1839.** In the year 1839, Count P. E. De Strzelecki, C.B., who was at that time engaged in a geological exploration of the Colonies, discovered auriferous pyrites in the Vale of Clwydd. He furnished a report to the Government on the subject of his discovery, and stated that the pyrites yielded "a very small quantity or proportion of gold, sufficient to attest its presence, insufficient to repay its extraction." Count Strzelecki published a work on the result of his explorations in the year 1845, but in this work he made no mention of his discovery of gold. Subsequently, however, in a Supplement to his book (published in 1846), he explained, as a reason for his silence, that he had been requested by Sir George Gipps "to keep the matter secret, for fear of the serious consequences which, considering the condition and population of the Colony, were to be apprehended."

Further proof of Count Strzelecki's discovery is afforded by a letter from that nobleman to Mr. Thomas Walker, of Sydney, and dated Wellington, 16th October, 1839. This letter was forwarded by Mr. Walker to the Editor of the *Sydney Morning Herald*, and was published by that journal on the 17th May, 1851. The following is an extract from the letter:—"On this side the Dividing Range the variety of rocks and embedded minerals augment; indications most positive of the existing silver and gold veins are met with. The want of means, however—that is, time and men—did not allow me to trace them to their proper sources. Why has the Government not sent heretofore a man of science and mineralogical and mining acquirements to lay open these sources of wealth still hidden beneath, and which may prove as beneficial to the State and individuals as the rest of the branches of Colonial industry?"

In a work entitled "Thirty Years' Residence in New South Wales," by Judge Therry, another letter from Count Strzelecki, on the subject of his discovery, is quoted. This letter was addressed to Captain P. King, R.N., and was dated from Wellington, 26th October, 1839. The following is an extract from it:—"I have specimens of excellent coal, some of fine serpentine with asbestos, curious native alum and brown hematite, fossil bones, and plants which I digged out from Boree and Wellington caves; but particularly *a specimen of native silver in hornblende rock, and gold in speck in silicate*, both serving as strong indications of the existence of these precious metals in New South Wales."

**1841.** On the 13th and 14th February, 1841, the late Rev. W. B. Clarke, M.A., F.R.S., discovered gold "in the granite and quartziferous slates west of Hartley, near the heads of Cox's River and Winburndale Rivulet." In 1842 he again discovered gold on the Wollondilly. In the year 1843 he announced his discovery to various Members of the Legislature, and shortly afterwards made it known generally. On the 9th April, 1844, he reported the matter to the Governor, Sir George Gipps, and showed him the gold. The Governor, however, decided that it would be better to "put it away," as it might lead to dangerous consequences. Mr. Clarke also mentioned to a number of people his belief that gold would be found in large quantities in the Colony.

Sir Archibald Geikie, Director of H.M. Geological Survey of the United Kingdom, in his "Life of Murchison," thus refers to Mr. Clarke's discovery of gold:—"The first explorer who proclaimed the probable auriferous veins of Australia on true scientific grounds, that is, by obtaining gold *in situ* and tracing the parent rock through the country—was the Rev. W. B. Clarke, M.A., F.R.S., who, originally a clergyman in England, has spent a long and laborious life in working out the geological structure of his adopted country, New South Wales. He found gold in 1841, and exhibited it to numerous Members of the Legislature, declaring, at the same time, his belief in its abundance. While, therefore, geologists in Europe were guessing, he, having actually found the precious metal, was tracing its occurrence far and near on the ground."

**1843-44.** A shepherd, named Macgregor, is said to have found gold in the Wellington district in 1843-44. This matter is referred to at considerable length in a book entitled "Gold Deposits in Australia," by Simpson Davison.

The following is an extract from page 348:—"By inquiring on the spot I have learnt that Macgregor had collected altogether gold of the value of about two hundred pounds sterling previously to the discovery of gold in placer deposits. This sum may appear to be small, but, considering that it was entirely obtained by breaking the surface quartz with a hammer, while following the occupation of sheep-tending, I should think that it not improbably represented a thousand separate instances of gold-finding between the years 1840 and 1850."

**1844.** Sir Roderick Impey Murchison, in the year 1844, examined a collection of rock specimens brought from Australia by Count Strzelecki, and he pointed out the great similarity between these and the auriferous rocks of the Ural Mountains which he had recently investigated. He mentioned that the Australian Mountain Chain, or Cordillera (from which the specimens had been collected), differed from the Ural and many other mountain chains," in having as yet offered no trace of gold or auriferous veins." In 1846, Sir Roderick wrote, "I now learn, however, that fine specimens of gold have been found in the western flank of the Australian Cordillera, particularly at the settlement of Bathurst, where it occurs in fragments composed of the same matrix (viz., quartz rock), as in the Ural. My friend and associate at the Imperial Academy of Petersburg, Colonel Helmersen, has recently suggested that a careful search for gold in the Australian débris will, it is highly probable, lead to its detection in abundance; I therefore encouraged the unemployed miners of Cornwell to emigrate and dig for gold."

In due course Sir Roderick Murchison's remarks were circulated in Australia, and were read by a Mr. W. J. Smith, amongst others. This gentleman, in 1848, forwarded some specimens of gold to Sir Roderick, and in 1849 he exhibited some more specimens to the Colonial Secretary. An official despatch, dated June 11th, 1851, from Sir C. A. Fitzroy to Earl Grey, specially refers to this matter in the following words: "About two years ago a Mr. Smith, who was engaged in some ironworks in the vicinity of Berrima, produced to the Colonial Secretary a lump of gold imbedded in quartz, which he said he had picked up at a certain place which he offered to make known to the Government upon being previously rewarded for the intelligence by the payment to him of a large sum. The obvious reply to this offer was, that the Government could enter into no blind bargain on such a subject, but that if Mr. Smith thought proper to trust to the liberality of the Government, he might rely upon being rewarded in proportion to the value of the alleged discovery, when that was ascertained. Mr. Smith refused to accede to this proposal, and there the matter rested."

**1849.** A shepherd boy was reported to have found a nugget of gold in the Pyrenees (Victoria) in the year 1849.

**1851.** The official despatch just referred to contains the following: "On the 3rd April, 1851, Mr. E. H. Hargraves, who had recently returned from California, addressed a letter to the Colonial Secretary to the effect that, having occupied himself for two months in exploring a considerable extent of country, in which, from his experience in California, he was led to believe gold was to be found, he had prosecuted his speculation to a successful issue, and offered to point out the localities where he had discovered gold to any officer or officers the Government might appoint, on condition that the Government would award him the sum of £500 as a compensation." To this suggestion a similar answer was given to that returned to the former proposal of Mr. Smith. Mr. Hargraves replied by a letter dated 30th April, 1851, that he was quite satisfied to leave the remuneration for his discovery on Crown land to the liberal consideration of the Government. He then stated that the localities where gold occurred were "Lewis Ponds and Summer Hill Creek, and the Macquarie River, in the districts of Bathurst and Wellington."

Mr. Hargraves was then requested to place himself in communication with Mr. Stutchbury, the Government Geologist, who was instructed to make a thorough examination of the localities where gold was said to occur. On the 14th May, 1851, Mr. Stutchbury forwarded a report to the Colonial Secretary, confirming the discovery.

According to the records of the evidence which Mr. Hargraves gave before a Select Committee of the Legislative Council, he proceeded to Guyong about a month after his arrival from California, and called at a hotel kept by Mrs. Lister. He then obtained the services of young Lister, promising that if he would guide him to Emu Creek, Lewis Ponds, and Summer Hill Creek he would show him where to find gold, and would let him have the first claim or mine. His object in wishing to go to these localities was, he said, that he had been there seventeen years previously, and from what he remembered of them, and from what he had recently seen in California, he thought it likely that gold would be found there. Arriving at Lewis Ponds Creek on the 12th February, 1851, he washed six pans of material from the bed of the creek, and obtained about five grains of gold. He then, accompanied by James Tom, went as far as Burrandong on the Macquarie River, and followed the latter up to the junction at Summer Hill. Here he found what he considered

*Photographed by E. F. Pittman.*

THE LOCALITY WHERE PAYABLE GOLD WAS FIRST DISCOVERED IN AUSTRALIA. JUNCTION OF LEWIS FONDS AND SUMMERHILL CREEKS, OPHIR.

sufficient to warrant him in bringing the matter before the Government. Hargraves now proceeded to Wellington as he wished to see the quartz vein from which he had heard Macgregor had obtained his gold. He found gold at Wellington, and also between there and Dubbo; then, after visiting Mitchell's Creek, he returned to Guyong, having been absent about a month. He instructed Tom and Lister how to make and use a miner's *cradle* or *rocker*, and advised them where to work during his absence, as he was obliged to visit Sydney. He appears to have travelled as far as Moreton Bay, and, during his absence, Tom and Lister again visited Summer Hill Creek, and there, with the aid of the cradle which they had constructed, obtained payable gold. It was then that Hargraves announced the discovery to the Colonial Secretary.

Mr. Stutchbury, the Government Geologist, on the 25th May, reported that at the diggings at Summer Hill Creek, within a distance of about a mile there were not less than a thousand persons, many of whom were getting large quantities of gold, and that the largest nugget found at that date weighed four pounds.

The news of the discovery of payable gold spread with amazing rapidity, and prospecting operations were immediately commenced all over the country, with the result that a number of the principal gold-fields were discovered the same year. On the 1st July, 1851, the Colony of Victoria was separated from New South Wales, and almost immediately afterwards the principal gold-fields, such as Ballarat, Mount Alexander, &c., were discovered there. The discovery of the Queensland gold-fields did not take place until some years later.

Mr. Hargraves was eventually granted the sum of £10,000 by the Government of New South Wales as a reward for his discovery, and was appointed a Crown Lands Commissioner. The sum of £2,300 was also granted him by the Government of Victoria.

## Modes of Occurrence of Gold.

Gold is present, in greater or less quantity, in rocks of almost every geological age in New South Wales. Thus it exists in reefs and lodes intersecting the Silurian, the Devonian, and the Carboniferous formations; alluvial gold has been successfully worked in the conglomerates of the Permo-Carboniferous Coal Measures at Tallawang, near Mudgee, where yields of from one to fifteen pennyweights of gold per load were obtained, and where individual nuggets weighing as much as five ounces were found. Amongst Triassic rocks the Hawkesbury sandstones have been proved in places to contain small quantities of fine gold. The gold, in these latter instances, appears to be disseminated in fine grains through the body of the stone, and as it does not appear to have undergone any natural process of concentration it is not probable that these rocks, which attain a thickness of about 1,000 feet, will ever prove a source of payable deposits of gold.

In Cretaceous rocks we have auriferous alluvial *leads* at Mount Brown, in the north-western corner of the Colony, where they are seen to be resting on Silurian slates (which themselves contain auriferous quartz reefs), and to dip underneath the Desert Sandstone.

Alluvial *leads* of Tertiary and Post Tertiary age were the principal sources of the precious metal won during the early years of gold mining. Auriferous quartz reefs also occur in many varieties of igneous rocks, such as Granites, Diorites, Felspar Porphyries, Serpentines and Felsites; and grains and crystals of gold also occur in the granites and diorites themselves, without any quartz reef as matrix. The presence of gold in these intrusive rocks, and also the fact that intrusive dykes of diorite, serpentine, porphyry, etc., are almost invariably found in proximity to rich auriferous quartz reefs or lodes, is strong presumptive evidence that the diorites, porphyries, and other eruptive rocks formed the media through which the gold was conveyed from great depths to the outer crust of the earth. Its presence in the quartz reefs is thought to be due to the agency of thermal waters, which leached it from the igneous rocks and deposited it, as well as the quartz, in fissures, the walls of which now bound the lodes.

*Extent of Gold-bearing Country.*—A glance at the mineral map at the end of this volume will show that gold-bearing rocks cover a very large area of the Colony. From the gold-field of Tibbooburra, in the north-west corner, to that of Panbula, on the south-east coast, is a distance of about 690 miles; while from the Delegate gold-field to Murwillumbah, on the Tweed River, is about 650 miles. Within these limits the Palæozoic and eruptive rocks have been proved to be payably auriferous at intervals. Much of the intervening country has not been prospected, and new gold-bearing localities are continually being discovered. Wherever the Palæozoic rocks rise above the surface of the Western plains they have been proved to contain deposits of gold of greater or less extent, and there is good reason to suppose that underneath the covering of Pleistocene soil, which obscures these rocks for hundreds of square miles on the arid plain country to the west of the 145th degree of longitude, there still exist many undiscovered gold-fields.

*Nature of Principal Gold Deposits.*—It has already been stated that gold has been detected in rocks of almost every geological age in this country. The principal deposits of gold, however, which have hitherto been worked with profit, are the following:—

1. Alluvial or detrital gold.
2. Auriferous reefs or lodes.
3. Impregnations of gold in stratified deposits, such as slate, quartzite, and volcanic tuff.
4. Impregnations in igneous rocks, such as granite, serpentine, felsite, etc.
5. Irregular deposits, such as bunches of auriferous ironstone.

*Photographed by E. F. Pittman.*

ALLUVIAL GOLD MINING.

Shallow Sinking (Pleistocene deposits). Seven miles north-west of Murrumburrah.

## 1. Alluvial or Detrital Gold.

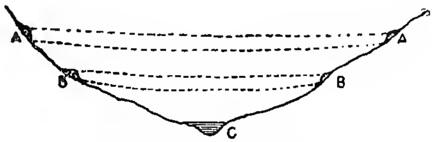
Payable deposits of detrital gold are found in—

(*a*) *Recent and Pleistocene alluvials.*
(*b*) *Beach sands along the sea coast.*
(*c*) *Tertiary alluvial leads.*
(*d*) *Cretaceous alluvial leads.*
(*e*) *Permo-Carboniferous conglomerates.*

1. (*a*) *Recent and Pleistocene Alluvials.*—The hardest rocks being liable to decomposition and gradual disintegration, owing to the action of the atmosphere, slow but sure denudation of the land is continually taking place. Quartz has the power of resisting denudation more than most other rocks, and hence it is that we frequently find quartz reefs standing up above the surface of the land like stone walls. Even quartz, however, has to succumb in the long run to the forces which are continually striving to destroy it, and, when the outcrops of quartz reefs are thus abraded, the grains of gold contained in them are set free on the surface. Thus it happens that the soil in the vicinity of auriferous reefs generally contains particles of gold, and advantage is taken of this fact by prospectors, who, by the process of washing the soil (termed "loaming"), trace the gold to its source in the reefs.

The gold set free from a reef, however, does not remain long in the position it first occupied. The rain constantly tends to wash it, together with soil and gravel, down to lower levels, and it is carried into the drainage channels, only coming to rest when the current of the stream slackens sufficiently. Subsequent rains carry down more gold, gravel, sand, and clay, and deposit them as before; but in the natural sluicing operations which are thus carried on, the gold, by reason of its greater specific gravity, has a tendency to become concentrated in the lowest stratum with the larger gravels, while the sand and clay are deposited in layers above it. This process is going on at the present time, and has been in operation ever since auriferous reefs were formed. The newest alluvial deposits formed in this manner are what are termed recent alluvials, and in some of these the shallow drainage channels may have been completely filled and the gold covered up by accumulations of sediment, while in other instances the deposits may occupy the bed of a large flowing river, such as the Macquarie or the Shoalhaven.

Alluvial deposits of earlier origin than these, but of later date than the Tertiary *leads*, are those known as Pleistocene alluvials. They occupy as a rule deeper channels than those previously described, and as these channels have been filled up with gravel, sand, and clay, the extraction of the gold necessitates comparatively deeper sinking. The rainfall towards the latter end of, and immediately subsequent to the Tertiary Period was very much greater in this country than it is at the present time, as proved by the greater width of the ancient river beds by which the rain water was conveyed to the sea. The comparative widths of the ancient and existing rivers is illustrated in many of our valleys, where, high up on their sides, may be seen the terraced




remains of the ancient river drifts which were once continuous from A to A. As the valley was gradually eroded, the old river gravel was redistributed at a lower level, forming a bed of Pleistocene drift extending from B to B. Later on this second river drift was again cut through, and was finally deposited in the bed of the existing river at C, which now contains recent auriferous deposits derived from the redistribution of the gold originally in the Tertiary (Pliocene), and subsequently in Pleistocene drifts. The great width of the old channel, A A, as compared with the bed of the present stream, is presumptive evidence of a much greater rainfall in Pliocene times.

It was to be expected that the recent and Pleistocene auriferous deposits of the Colony, being the most accessible, would be the first to be discovered, as, in fact, they were; and for a similar reason it was natural that they should be the first to be exhausted.

Pleistocene and recent alluvial deposits occur in connection with most gold-fields where auriferous reefs have been found.

1. (*b*) *Beach Sands.*—Along the coast of New South Wales, and particularly in the north, near the mouth of the Richmond River, deposits of black sand, containing fine grains of gold, platinum, and oxide of tin (cassiterite), are left in patches after each high tide, especially in heavy weather. In 1870 it was first discovered that the gold was present in payable quantity, and the sand has been worked at intervals ever since, though the presence of the platinum was not recognised until the year 1878. A careful examination of the sand proved that it is composed chiefly of small zircons, with ilmenite (titaniferous iron), a little quartz, garnet, tinstone, platinum, and gold. In 1895 an old *raised beach* or terrace was discovered extending inland from near the present beach. In this terrace a seam of compact black sand-rock, from 3 feet 6 inches to 5 feet thick occurs, carrying payable gold, and there is no doubt that the auriferous black sand deposited on the beaches after heavy storms, is released from this sandrock, or old raised beach, by the action of the waves. The original source of the gold now found in the sand-rock has been the subject of some controversy. It was, at one time, thought to have been derived from the basalt in the neighbourhood, because several tons of this rock were said to have yielded

*Photographed by E. F. Pittman.*

Alluvial Gold Mining—80-feet sinking.—Jawbone near Wellington.

as much as twelve pennyweights of gold per ton. A considerable number of fire assays of samples of the basalt has, however, failed to confirm the results referred to. It is more probable that the gold was derived from a Tertiary drift which underlies the basalt, and the redistribution of which has been gradually effected by the action of the waves in Post-Tertiary times. An interesting fact in connection with this view is that, although the beach sands have been tested along some hundreds of miles of coast line, they have only proved payable in the immediate neighbourhood of basalt. The proportion of gold in these deposits is very small, and the gold is in a very fine state of division. It is necessary, therefore, to treat the material by a process of concentration, and the method adopted is to pass the sand, in a state of suspension in water, over inclined tables covered with strips of carpet or cocoanut matting. The concentrates are then collected by washing the strips of carpet in a tub of water, and are passed several times over amalgamated copper plates, which retain the gold.

The sandrock in the *raised beach* (which is known as McAuley's Lead) has first to be crushed with wooden mallets and passed through a screen. It is then concentrated on the carpet-covered inclined table, and the concentrates are washed in a solution of caustic soda before being passed over the amalgamated copper plates. The object of this treatment with alkali is to remove the organic matter which coats the grains, and thus to facilitate the amalgamation of the gold.

Several parallel raised beaches have been discovered in this locality, but so far McAuley's Lead is the only one of them which has proved payable.

1. (*c*) *Tertiary Alluvial Leads, or Deep Leads.*—When the more easily won gold from the Recent and Pleistocene alluvial deposits had become gradually scarcer, owing to the efforts of the hordes of miners who had been engaged in extracting it from the earth in the earlier days of gold-mining, the precious metal was traced by the more enterprising workers into the deep alluvial *leads.*

These *leads* represent the beds of old rivers which formed the surface drainage channels in Pliocene times. Their geôlogical age has been determined by the fruit (nuts) and leaves which, together with fragments of fossil wood, trunks of trees, and occasional specimens of freshwater shells (*Unio*) occur plentifully in them. The pebbles forming the drifts consist principally of white quartz; but there are others composed of granite, porphyry, diorite, slate, &c., similar to rocks known to exist in the neighbourhood. They are always very round, or waterworn, and in this respect generally offer a marked contrast to the pebbles of the Pleistocene and Recent drifts, which are subangular, owing to their having undergone less abrasion by the action of running water. The Pliocene *leads* have, in a majority of cases, been covered up by a considerable thickness of basalt owing to wide-spread volcanic eruptions, which, about the close of the Tertiary Period, resulted in the filling up of the principal river valleys by streams of lava. The depth of the drifts below the present surface of the ground is, consequently, considerable, ranging up to several hundred feet, and hence they are commonly called *deep leads*. Moreover the auriferous gravel frequently contains large bodies of water, and therefore the difficulties in the way of extracting the gold are very great, and, in a great many cases, quite beyond the means of ordinary miners. A very large amount of capital is required, not only for the purpose of sinking the shaft through considerable depths of wet, and sometimes *running* ground (quicksands) but also for providing efficient pumping, and winding machinery.

In consequence of these difficulties in the way of mining, most of the deep *leads* discovered in this Colony were worked by parties of ordinary miners until the increasing depth and wetness of the workings were too much for the appliances at their command, and were then abandoned. The gold-fields of Forbes, Gulgong, and Uralla, amongst others, offer great advantages for the employment of capital in providing the necessary machinery to reopen and systematically exploit these abandoned auriferous *leads*.

The first alluvial leads in New South Wales necessitating deep sinking were discovered at Forbes in 1862. In January of that year rich alluvial gold was found at the surface near the base of the low hills on the north bank of the Lachlan River, and the deposit was soon traced down into a deep *lead*. The result of this discovery was that within four months there was a population of 28,000 people encamped on the site of the present township of Forbes. By the end of the year the number had decreased to 12,000 persons, notwithstanding the fact that no less than 235,043 ounces of gold had been produced from this field within less than twelve months. During the next six months, ending 30th June, 1863, the yield of gold from the Lachlan goldfield was 50,818 ounces, and the population had decreased to 3,500 persons. None of the *leads* were traced to their termination owing to the difficulty of dealing with the water, and the fact that the small areas which were tenable under miners' rights did not warrant the employment of sufficient capital to provide proper machinery. To the north-west of the town of Forbes a shaft was put down to a depth of nearly 400 feet, in very waterworn Pliocene drift, but was not bottomed, and, consequently, this *lead* (the North Lead) was not tested where the indications were, perhaps, the most favourable. The size of the claims held on the alluvial *leads* was only 40 feet x 40 feet, and it is recorded that a party of six men worked out one of these claims, on the South Lead, in two months, during which period they won 1,900 ounces of gold. It is well known that in those days, when miners were always ready to start off for the scene of the latest (and therefore most attractive) *rush*, the work, especially in deep *leads*, was hurriedly and imperfectly performed; and there is good reason for believing that in such gold-fields as Forbes the washdirt was in many instances only extracted from the main channels, leaving the side, or *reef wash*, as well as that from the junctions of smaller tributaries, untouched. With the aid of suitable appliances, therefore, it is probable that much of the old ground would pay to work over again. Quite a number of *leads*, which have only been partially worked, occur in this gold-field, and there can be little doubt that if they were developed further down their course they would be found to junction with others not yet discovered.

In the immediate vicinity of the township of Forbes the country is undulating, and consists of low hills of Upper Silurian sandstone and granite, but surrounding these are level Pleistocene plains, which render it difficult to trace the course of the old river beds. The altitude of Forbes is 781 feet above sea level.

Gold was found in Tertiary *leads* at the Rocky River, near Uralla, in 1856, but here, owing to the altitude (3,335 feet at Uralla) and the broken character of the country (there being deep valleys on all sides of the hills, on which, under a covering of basalt, the auriferous gravels were first discovered), the miners were able to extract the gold without being troubled by water. Moreover, the basalt has been removed, by denudation, from a considerable portion of the *lead*, so that, at the locality known as Sydney Flat, the greatest depth of sinking was about 70 feet, and the auriferous gravels had here their maximum width, viz., 10 chains. In the narrowest portions of the old river-bed the wash-dirt yielded as high as two ounces of gold per load; but where the width of the drift increased, its gold contents diminished in a corresponding degree. To the north-east of Sydney Flat the *lead* again dips under a high basalt table-land, the depth of sinking increases, and water is met with in considerable quantities. Mining operations have not been carried on to any great extent in this direction, and there is little chance of the *lead* being developed along its north-easterly course, unless the work be undertaken by companies in possession of plenty of working capital. There is room here, however, for legitimate investment, and the proper course to pursue would be to first locate the position of the old channel under the basalt table-land by means of a series of bores, and then, if the prospects were sufficiently promising, to erect machinery capable of coping with the difficulties which are to be expected in mining under such conditions.

The Rocky River gold-field was notable also for its rich Pleistocene and recent auriferous alluvials, and the records show that in the year 1858, 17,277 ounces, and in 1859, 16,101 ounces, of gold were despatched from Uralla to the Mint under police escort.

The older rock formations in the vicinity of the Rocky River gold-field are granite, dark blue and brownish claystones, of Carboniferous age, and hornblendic granite which is of an intrusive character, and from which the gold has, most probably, been derived.

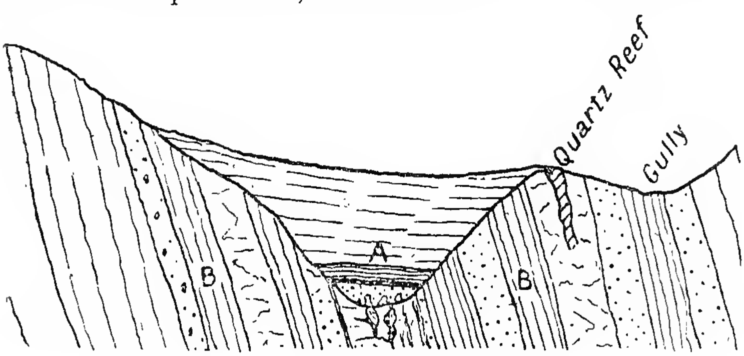
The Tertiary *deep leads* of Gulgong were discovered in the year 1871, and so productive were they that within the succeeding five years nearly thirteen and a quarter tons of gold were sent away from the field under police escort. The yields for each year were as follow:—

| | oz. dwt. gr. | | oz. dwt. gr. |
|---|---|---|---|
| 1871 ... ... | 76,315 0 12 | 1874 ... ... | 68,354 19 15 |
| 1872 ... ... | 134,455 16 1 | 1875 ... ... | 32,073 13 2 |
| 1873 ... ... | 120,552 11 16 | | |

The auriferous gravel, or *wash dirt*, which was composed principally of quartz pebbles, and which contained trunks of trees, fragments of kerosene shale, and fossil leaves and nuts, was overlaid by a considerable thickness of clay and cement, and in many places by basalt also. The greatest depth of sinking was about 200 feet.

In some of the *leads* the wash-dirt had a mean width of 300 feet, by a depth of one foot, while the average yield of gold was one ounce per load. In the Happy Valley Lead the wash was fifteen inches thick, and the average yield an ounce and a half per load, while the richest part of it yielded twelve ounces per load. In No. 7 claim on this lead, 1,546 loads of wash-dirt were extracted for a return of 6,203 ounces of gold, or an average of four ounces five grains per load. In the Canadian Lead one tin dishful of wash-dirt, taken from No. 15 claim, contained thirty-five ounces of gold, and 400 loads from the same claim yielded at the rate of three ounces per load.

The older rocks in the Gulgong gold-field are granite and Upper Silurian schists and limestones, which are intruded by dykes of diorite. In places the bed of the Happy Valley Lead was found to be composed of crystalline limestone, in which large fissures or caverns, some of them filled with pebble drift, were met with.




Sketch Section across the Happy Valley Lead.
(After C. S. Wilkinson.)

The following were the principal *leads* in the neighbourhood of Gulgong:—The Black Lead, the Happy Valley, the Star, the Cosmopolitan, Dead Man's Lead, the Caledonian, the Perseverance, Nil Desperandum, Canadian, Home Rule, &c.

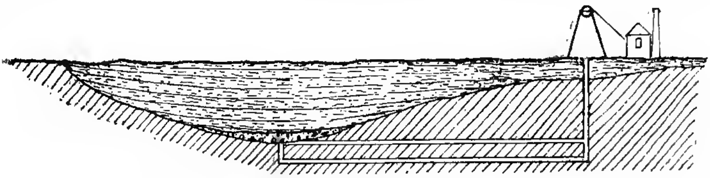
Many of these leads were abandoned because the wash-dirt became somewhat poorer, and the influx of water too great to allow of their being profitably worked without the aid of steam machinery. To this day their continuation into the deeper ground has not been traced, and there can be little doubt that, by the judicious expenditure of capital in boring through the basalt, and in the erection of suitable pumping and winding machinery, they could be made to yield satisfactory returns to investors.

Strange to say, no auriferous reefs of any importauce have yet been discovered in the vicinity of the extremely rich *leads* at Gulgong; so that the immediate source of the gold found in the latter has yet to be proved, though the presence of dykes and masses of diorite in the hills from which the principal *leads* diverge renders it probable that productive reefs do occur in the vicinity.

It would not be practicable, in a small treatise such as this, to describe all the Tertiary *leads* of the Colony; and reference has been made to those of Forbes, Uralla, and Gulgong, chiefly because it is thought that they are typical examples of deep alluvial deposits which have been abandoned before they could, in any sense, be considered to have been worked out, and because, therefore, they represent instances in which the employment of capital in reopening old auriferous deposits could be regarded in the light of legitimate investment. Similar alluvial auriferous deposits occur in a number of other gold-fields in various parts of the Colony, such as Adelong, Albury, Braidwood, Grenfell, Gundagai, Rockley, Temora, Tumberumba, &c., &c.

In the neighbourhood of Corowa, on the Murray River, auriferous *leads* have recently been developed, which are likely to have an important influence on the future of deep alluvial mining in this Colony. The celebrated Chiltern Valley Leads, in the neighbouring colony of Victoria, have been worked with great profit for a distance of about eighteen miles from their source at the township of Chiltern, down nearly to Wahgunyah; and the township of Rutherglen owes its existence and present prosperity to the success of these alluvial mines. The direction which the main lead was found to assume, as it was gradually traced towards the Murray, left no room for doubting that it must cross under the river into New South Wales territory. Accordingly, a series of bores were put down in the vicinity of the town of Corowa, and by these means the occurrence of quartz pebble wash, at a depth of 300 feet, and containing good prospects of gold, was proved. The depth at which this drift was found, however, shows that it must occur in a tributary, or branch lead, and not in the main gutter, for the latter, on the Victorian side of the Murray (that is to say, at a point higher up its course), has a depth of about 400 feet.

The Corowa Deep Lead Gold-mining Company have secured a lease of a considerable area of the land which was proved by boring, and are now sinking a shaft which they intend to carry to a depth of 325 feet. From near the bottom of this shaft a *drive* will be excavated in the bed rock for a distance of about 1,100 feet, or until it reaches a point underneath the centre of the *lead*; a *rise* will then be put up from the end of the tunnel to the bottom of the drift, and the water, which would otherwise prevent the extraction of the auriferous wash-dirt, will be drained, through this tunnel, to the bottom of the shaft, whence it will be raised to the surface by means of powerful Cornish pumps.



CROSS SECTION OF DEEP AURIFEROUS LEAD ON THE LOWER MURRAY, NEAR COROWA.

The sketch illustrates the method on which these deep *leads* are usually opened. The country consists of level plains, the surface of which is composed of Post Tertiary clays. The sinking of the shaft is generally attended with very great difficulty, by reason of the extremely wet or running ground which is met with. The old valleys, on the bottom of which the auriferous gravel reposes, were very wide; so that at a distance of even 1,100 or 1,200 feet from the centre of the main gutter a considerable depth of *running* ground is often met with, and, in several instances, shafts have been lost from this cause. While working in a mine of this description in Victoria, in 1895, six men lost their lives through irruption of slum or liquid mud.

In order to convey some idea of the cost connected with the opening of these deep alluvial mines, it may be stated that, in the Rutherglen district, one Company has already expended £39,000 in what may be termed preliminary expenses, including £16,000 for surface plant, and it is estimated that a further expenditure of £20,000 will be necessary before any return can be obtained. They have, however, proved the course of the *lead* through their property by systematic boring, and are confident that, in the future, profitable results will crown their enterprise. This mine is fitted with a pair of Cornish pumps of twenty-two inches diameter. At another mine in the same district pumping operations were carried on for six years in a fruitless effort to drain the mine. It was at last recognised that the pumps were not sufficiently powerful, and it was not until two Cornish lifts, of eighteen inches diameter, were installed that the desired result was obtained.

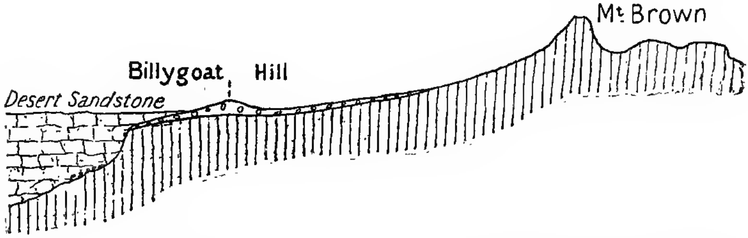
The course of the main *lead*, the working of which has proved such a successful industry on the northern border of the Colony of Victoria, has not yet been traced in New South Wales territory; but there can be little doubt that it does occur there, and present indications point to the probability of its passing under the Quat Quatta pastoral estate, to the east of Corowa. An English syndicate was understood to have arranged with the proprietors of the estate to spend £10,000 in prospecting for the *lead* by boring, provided a lease of several thousand acres (under the Mining on Private Lands Act) were obtained from the Government. Unfortunately the agreement fell through recently. There is no doubt that this is a matter well worthy of the attention of capitalists; for, if the main Chiltern Valley Lead were proved to cross under the Murray River, there is every probability that it would be as rich in this Colony as in Victoria.

In this connection, the operations of the Corowa Deep Lead Gold-mining Company will be watched with great interest. The gutter located by their bores is, in all probability, a tributary of the main Rutherglen Lead; and if their operations be successful, as there is good reason for believing they will, they will be the means of opening up a large area of hitherto unprospected country, and the mining industry may be expected to flourish, for many years to come, in the neighbourhood of Corowa.

About thirty-five miles further east, in the vicinity of Albury, a line of bores has been put down by the Government of New South Wales for the purpose of prospecting for deep *leads* trending from the auriferous deposits of the Black Range. The boring operations have been so far successful that two deep gutters have been located, each of which yielded promising prospects of gold. It is probable that the land will be leased in large areas, provided the lessees show an intention to provide sufficient capital to successfully exploit these deep and watery deposits.

1. (*d*) *Cretaceous Alluvial Leads*.—In the far north-western corner of the Colony occur some auriferous alluvial deposits, which are, undoubtedly, of greater geological age than any of those previously described. Mount Brown consists of an isolated range of Silurian slates, rising above the surrounding plains, which are composed of Upper Cretaceous sandstone (commonly known as Desert Sandstone), overlaid in places by Pleistocene and Recent deposits. The slates, of which Mount Brown is composed, are vertically bedded, and contain numerous quartz reefs, which, however, have not been prospected to any considerable extent. At the south-western flank of the Mount Brown range, a *lead*, composed chiefly of very waterworn white quartz pebbles, but containing also some pebbles of slate and quartzite, is exposed, for about four miles, on the sloping surface of the Silurian rocks. This drift, or *lead*, can be seen, from the low ground, to extend up the slope of the hills, and its colour contrasts so markedly with the dark surface of the slates that it has the appearance in the distance of a white macadamised road. As it approaches the plains in its downward course, it is seen to form a small foothill—Billy-goat Hill—the surface of which has been worked for gold to a considerable extent

but on being followed further down to the south-west, the lead is found to dip beneath the surface of the plain, the upper portion of which is formed of Desert Sandstone.




Within a short distance south-west of Billy-goat Hill, the Mount Brown Gold-mining Company's shaft was sunk to a depth of 240 feet, when a heavy influx of water was met with, and the shaft was abandoned without reaching the auriferous drift. Some very rich yields of gold were obtained from the workings about Billy-goat Hill, and one nugget of twenty-eight ounces was found. The higher portions of the *lead*, on the slopes of the range, have suffered greatly from denudation—so much so that the walls of the old valley have been entirely removed; moreover, the quartz pebble drift itself, as well as the gold which it contained, has been washed down to lower levels, and reconcentrated in gutters of later age, whence the precious metal has been recovered by the miners.

Other instances of auriferous *leads* of Cretaceous age occur in the neighbourhood of Tibbooburra, about twenty-five miles N.N.E. of Mount Brown. Here there is a small patch of hornblendic granite, almost surrounded by Silurian slates, which are intersected by quartz reefs. There has been a considerable amount of *surfacing*, or shallow working for gold, on the granite country in the vicinity of the township of Tibbooburra, and in some cases alluvial gutters have been traced to where they dip to the eastward, under the Desert Sandstone. The latter formation evidently, at one time, extended over the whole of this country, forming a covering to the granite and Silurian slates, but was subsequently removed from a considerable area by denudation. Nuggets of gold weighing fifteen and twenty ounces, respectively, were discovered in the alluvial workings at Tibbooburra. It is probable that the gold in these drifts has been derived both from the granite rocks and from the quartz reefs which intersect the Silurian slates.

As these *leads* at Mount Brown and Tibbooburra dip under the Desert Sandstone, and probably rest upon the Rolling Downs formation, their age may be provisionally regarded as Middle Cretaceous.

There is another instance of the occurence of detrital gold in Cretaceous rocks, about one hundred miles from the last-mentioned locality, viz., at the Peak, between Kayrunnera and Tarella Stations, on the road from Milparinka to Wilcannia. The Peak is an isolated, conical hill of Upper Silurian slate, capped (unconformably) by Upper Cretaceous quartz and ironstone conglomerate. In the adjoining hills to the north of the Peak, the conglomerate dips to the north-east under a considerable thickness of Upper Cretaceous sandstone. A fair amount of alluvial gold has been obtained by following the ironstone conglomerate to the dip, and also by working the recent gullies which intersect it, and in which the gold has been reconcentrated.

In the neighbourhood of Pretty Gully (fifteen miles from Drake) the conglomerates forming the base of the Triassic, or Clarence River Coal Measures, contain detrital gold, though apparently not in sufficient quantity to be payable. The gullies, however, which, in Post Tertiary times, have been cut through these rocks, and in which the gold, derived from the denudation of the conglomerates, has been concentrated, has been profitably worked in a number of instances.

1. (*e*) *Detrital Gold in Permo-Carboniferous Conglomerates.*—The only instance known of the occurrence of detrital gold in payable quantities, in rocks of Palæozoic age is the one already alluded to, in the neighbourhood of Tallawang, to the north of Gulgong. Here the conglomerates forming the basal beds of the Upper Coal Measures, were, in the year 1875, worked successfully for gold. Yields of from one to fifteen pennyweights of gold per ton, and nuggets up to five ounces in weight were obtained from it. It is doubtful, however, whether this deposit forms a definite alluvial *lead* of any great extent. The conglomerates were, doubtless, deposited in an estuary, and it is probable that the auriferous portions of them were laid down along the shore line which received the surface drainage from some old auriferous rocks, and that the gold derived from the denudation of these latter was thus distributed amongst the pebbles. While, therefore, it is not unlikely that similar auriferous conglomerates may be found to occur in patches elsewhere, the existence of payable quantities of gold in these rocks, over considerable areas, is scarcely probable.

### *Gold Dredging.*

It has already been stated that the beds of many of our running streams contain gold in their gravels, and there is reason to believe that, in a number of instances, these deposits are richer than the Tertiary or Pleistocene drifts. Many rivers are continually changing their courses, and in doing so, they cut through the older deposits of auriferous drift, and, acting as natural sluices, they concentrate in their beds the gold washed from these older deposits. Again, in many of our river valleys older auriferous drifts occur at considerable elevations above the bed of the present stream, marking the positions which the river bed occupied in Tertiary and Pleistocene times. These older drifts have been continuously subjected, since their deposition, to the destructive operations of the atmosphere, and their gold contents have, for long periods, been washed down the sides of the valley by rain and running water into the stream below, where they have been naturally sluiced or concentrated by the action of the water. Not only has this action been going on for many centuries, but it is in operation at the present time; and every creek, which finds its way through auriferous country to a river, may be regarded as contributing its quota to the enrichment of the gravels in the river bed. In view of these considerations, it is not difficult to believe that some of our existing rivers, confined as they are to much narrower channels than were the ancient rivers, and receiving the drainage of wide areas of auriferous country, should contain in their beds extremely rich deposits of gold. Miners, generally, are thoroughly alive to the conclusions just mentioned; but it is, as a rule, extremely difficult for them to extract the gold from the gravels in the beds of the river, on account of the presence of such large bodies of water. In exceptionally dry seasons it is possible to work portions of such deposits, and this has been done in a number of instances with considerable profit, the gravels being removed and treated in ground sluices. Again, in some cases, it is possible to divert a stream to one side of the valley by means of a dam, and then extract the gold from that portion of the gravel from which the running water has been excluded. Where a river makes a *horseshoe* bend, again, it is frequently practicable to drain the bend by making an open cutting, or a tunnel, across the neck or narrowest part of the enclosed land, and thus divert the water. Still, the fact remains that it has been impracticable in many cases to extract, by ordinary methods, the gold which is believed to exist in our river beds.

In New Zealand the difficulty has been solved by the introduction of gold dredges. The industry of gold dredging has been in existence in that Colony for some years; but great improvements have recently been made in the appliances used, with the result that enormous profits are now being obtained, and the method has been demonstrated to be the most economical for saving gold hitherto practised in the world. Gravels, containing at the rate of only one grain of gold per cubic yard, have been made to yield handsome profits, and so efficient is the machinery for the saving of extremely fine gold, that a hundred of the small particles of gold recovered by a dredge were found to weigh, in the aggregate, only ·097 grains; their average weight was, therefore, slightly less than one-thousandth of a grain.*

A special pamphlet on the subject of gold dredging, written by Mr. J. B. Jaquet, Geological Surveyor, was published by the Mines Department of New South Wales, in 1898, and has been the means of directing a considerable amount of attention to the question of the successful working of the river beds of this Colony.

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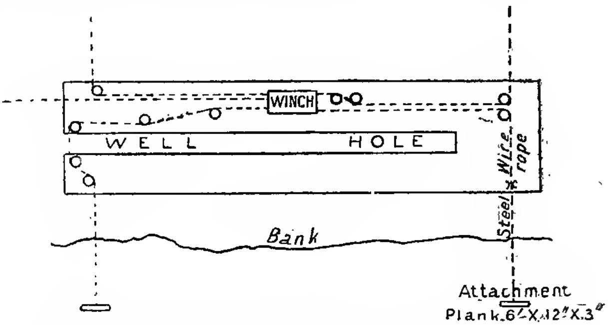
* New Zealand Mining Journal, 1st September, 1897, p. 296.

The following is an outline of the process:—

The dredge consists of a strongly-built pontoon, having an open well-hole extending down its centre for about two-thirds of its length. Over the inner, or rear, end of this well-hole is pivoted one extremity of a beam, called a "ladder," which is furnished with rollers at each end, over which revolves an endless band, having buckets attached to it at intervals. The free, or forward, end of the ladder can be raised or lowered at will, by ropes and pulleys, suspended from a frame, called a gantry, fixed in the bows of the pontoon; and, by means of this gear, the buckets can be made to excavate gravel at any depth down to about forty feet below the surface of the water. The endless belt, carrying the buckets, is caused to revolve on its rollers by a steam engine. At intervals on the belt one of the buckets is replaced by a grab, for the purpose of catching up very large boulders. Just abaft the pivoted end of the ladder, and extending lengthwise towards the stern of the pontoon, is placed a cylindrical trommel, or revolving screen, which is slightly inclined from the horizontal. The perforations in this screen increase in size towards its lower end, where they measure about half an inch in diameter. The gravel, as it is brought up by the buckets, is discharged through a shoot into the trommel, where it meets a strong spray of water issuing from a perforated pipe. As the trommel revolves, the finer material, carrying the gold, is washed through the perforations and falls upon inclined tables, while the coarser portions of the gravel, including the large boulders, pass through the inclined cylindrical trommel, and are raised by an elevator and discharged in the rear of the dredge. As the ejected material occupies a larger space than the gravel did before it was excavated, the elevator is so arranged that it can deliver the waste material at the top of a heap from twenty feet to forty feet high, if necessary. Briefly stated, the method involves the excavation of the auriferous drift from the front of the dredge, and the stacking of the tailings, or waste material, at the stern. The inclined tables, upon which the finer material with the gold falls, after issuing from the perforations of the trommel, are covered with cocoanut matting, and upon the top of this is laid either wire netting or a plate of what is termed "expanded metal." This consists of wrought-iron, perforated with slots, one side of each slot being raised slightly. These form riffles, and serve the purpose of catching the grains of gold. The tailings from the tables pass into a launder, by which they are conveyed to the stern of the dredge. The cocoanut matting from the first table is rinsed in a box of water every night, and those from the other tables are washed once a week, for the purpose of collecting the concentrates. The washings or concentrates are then treated in what is termed a "streaming-down box," in which the gold is finally separated from the last traces of the worthless material.

The dredge is moored by five wire ropes, viz., two on the port side, two on the starboard side, and one (head line) from the bows. The outer ends of these ropes are firmly attached to stout planks buried in the soil. The inner ends pass round pulleys fixed on the deck of the dredge, and are attached to the barrels of steam winches, so that, by means of the winches, the dredge can be moved laterally, in either direction, or forwards, as desired.

The dredge is capable of cutting a channel for itself into the bank of a river, and thus letting in the water necessary to keep it afloat; and as many rivers are bordered on either side by wide alluvial flats, which have been formed by the stream changing its course from time to time, the whole width of these flats can be dredged down to the bed-rock, and the gold recovered. The dredge can also be launched in a hole, excavated by manual labour, in one of these alluvial flats; and as the draught of a large dredge is only about 3 feet 6 inches, sufficient water will generally drain into the excavation from the surrounding gravels to keep her afloat.




SKETCH ILLUSTRATING METHOD OF MOORING DREDGE.
(After J. B. Jaquet.)

The dredge works three (eight-hour) shifts per day, and requires a crew of six men, besides a master; the latter, however, may superintend the work of several dredges. Two men are required for each shift. One of these attends to the steam winches, and gives the dredge a slight lateral travel whenever he sees the buckets begin to come up empty; the second man attends to the engine, and acts as stoker. The remainder of the work is entirely automatic.

With regard to the success of the dredging industry in New Zealand, Mr. Jaquet mentions one instance where a dredge, which cost £5,000 to build, obtained more than sufficient gold to pay for itself within seven weeks after starting work. Another small dredge obtained £3,570 worth of gold as the result of two months' work. A third, belonging to the Clyde Dredging Company, Limited, recovered gold to the value of £10,156 for nine months' work. In this last instance the capital of the company was only £4,000.

*Photographed by E. F. Pittman.*

GOLD DREDGING IN THE ARALUEN VALLEY.

The Araluen Proprietary No. 1 Dredge.

The principal question of interest, so far as the Colony of New South Wales is concerned, is whether the conditions under which the auriferous gravels occur in our rivers are favourable to the employment of dredges? It has been contended by some persons that dredging cannot be successfully carried out in this Colony on account of the uneven nature of the slate bottom which characterises many of the rivers, and which would prevent any gold lying in crevices from being recovered by the buckets. There is no doubt that the New Zealand rivers (the Clutha and its tributaries) are exceptionally favourable for dredging, by reason of the general character of their bed-rock, their depth of water, and the enormous extent of their alluvial flats. The New South Wales rivers may not possess so many advantages in these respects; nevertheless, successful results have already been obtained in a number of cases, and it is hoped that any difficulties that may arise in the future will be overcome. In regard to this question, Mr. Jaquet remarks*:—

"It is necessary, however, that one should be very cautious in expressing an opinion as to whether a river bottom is adapted for dredging or otherwise. Indeed, when the drift deposits extend to a great depth, this question can only be satisfactorily answered after prospecting operations have been carried out. In several places upon the Clutha the same schists, which appear hard and unyielding upon the bank, have been found to be soft and pliable beneath the river. In working upon flats, or in shallow, sluggish rivers—and the majority of our New South Wales rivers are of this character—it may be possible to dredge close down to the bottom, and finally clean the same with the aid of divers. For the purpose of raising the small quantity of gravel which the buckets were unable to reach, and for cleaning out the crevices, sand-pumps, controlled by the divers, might, perhaps, be used with advantage. The rapid current would render it dangerous to employ divers on the Clutha."

"In this connection it is important to note that the gold, in many river drifts, is not confined to the bottom, but is more or less evenly distributed through a considerable thickness of gravel, or a portion of it may have been deposited upon a false bottom, at some distance above the bed-rock. While prospecting the auriferous gravels upon the Sholhaven River, in 1893, I obtained, in many instances, a higher yield of gold from a false bottom than from the bed rock below, and several beds of gravel were tested in which no concentration of the precious metal upon the bottom could be detected. It is obvious that, under such circumstances, dredging might be profitably carried on, notwithstanding the presence of a hard rough bottom."

"Another impediment to the industry is to be found in the occurrence of decaying logs or tree stumps. The Clutha is practically free

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* Mineral Resources, No. 3: Notes on Gold Dredging 1898, p. 15.

from these obstacles; but they have given considerable trouble to the dredges working the Buller River, upon the West Coast of New Zealand."

All the rivers of New South Wales which drain auriferous country have now been taken up for dredging purposes. Many dredges are in course of construction, while at least a dozen have already started operations, and the result must cause a considerable increase in the production of gold in the near future. Mr. C. L. Garland's dredge was the first to start, in 1899, on the Macquarie River, near Stuart Town, and the proceeds are understood to be satisfactory, although considerable difficulty was met with, owing to the occurrence in the bed of the river of an extremely hard cement, which caused great wear and tear on the buckets and machinery generally, necessitating frequent stoppages for repairs. The experience gained in this instance has been taken advantage of in the construction of later dredges, and the lips of the buckets are now being made much stronger.

The following are the particulars of the pioneer dredge of New South Wales, owned by Mr. C. L. Garland, and working on the Macquarie River:—Length of pontoon, 100 feet; beam, thirty-one feet; depth, six feet six inches; draught, when loaded with 100 tons of machinery, three feet six inches; total dead weight of dredge, 200 tons; steam power required, seventy-five horse-power (actual); capacity of dredge, twelve buckets per minute; capacity of buckets, four and a half cubic feet each.

The dredge is provided with three steam engines. The main engine is for actuating the buckets. The second is to work the winch, with six drums. The third engine is to work the electric light. The ladder is sixty-eight feet long, and is fitted with thirty-eight buckets, and two grab hooks, which will lift boulders up to one ton in weight. The weight of the ladder is fifteen tons, and with the buckets attached it weighs twenty-five tons. When the ladder is inclined at an angle of 45° the machine will dredge to a depth of forty feet below the water-line. The trommel is twenty feet long, and has an inside diameter of five feet. The dredge is fitted with a twelve-inch centrifugal pump, playing water on the gravel in the trommel from a perforated pipe. The capacity of the pump is 2,000 gallons per minute. The elevator will stack the coarse boulders twenty-five feet above water level. There are ten inclined tables, five on each side of the trommel, and arranged back to back. The length of the tables is sixteen feet, and they are covered with cocoanut matting and expanded metal. The fine tailings escape by launders from the bottoms of the tables, and are conveyed to the stern of the dredge.

Bucket dredges of several other types are now at work in different parts of the Colony; thus, in some a pair of revolving screens is used instead of one, while at Araluen two dredges are to be seen without either screens or elevators. In the latter case the gravel is discharged

*Photographed by E. F. Pittman.*

GOLD DREDGING.—GARLAND'S No. 1 CREDGE MACQUARIE RIVER

direct from the buckets into a sluice-box, which delivers the tailings at the rear of the dredge, while the gold is caught in a variety of riffles. Some of these are formed of longitudinal bars, others of angle-iron placed transversely, and others, again, consist of perforated iron plates resting upon coir matting. It is claimed that as much, and as good, work can be done by a dredge of this construction as by one fitted with a revolving screen, and that the initial cost is appreciably less. On the other hand, there is considerable wear and tear of the riffles in the sluice-box, owing to the big stones and boulders being carried over them; moreover, it seems probable that the saving of fine gold would be assisted by the action of the revolving screen in separating the large stones and allowing only the finer material to be treated on inclined tables.

However, experience with the different types of dredges will soon determine which are the most suitable for the different conditions met with in various localities. It is obvious that those dredges which have no elevators can only work in deposits of limited depth, since the tailings occupy more space than the original beds of gravel. If, therefore, the deposit be more than fifteen or twenty feet deep, the only way to find room for the tailings is to deposit them in high stacks; and hence the necessity for elevators.

Another method of dealing with auriferous gravels is by means of what are known as pump dredges, which have been introduced into this Colony from Victoria. The term pump-dredge is somewhat of a misnomer, since the machines do not work by dredging. The process consists of hydraulic sluicing, the necessary pressure being given to the water by means of a powerful centrifugal pump. The water, and the gravel which it breaks down, gravitate into a suction well or sump in the lowest part of the workings, and from this they are raised by another centrifugal pump, and delivered into sluice-boxes at a height of about fifty feet from the floor of the excavation. The bottom of the sluice box is fitted with the usual riffles, which retain the gold, while the water, carrying with it the gravel, flows over the end of the box to the dump. The machinery is all fitted on a pontoon, so that it can be floated to a fresh position when desired. When work is about to be commenced on a deposit, an excavation is made of sufficient size to accommodate the pontoon; the water is allowed to accumulate in this and the dredge is launched. The excavation is then drained by means of the centrifugal pump, so that the pontoon can rest on the bottom, and the bank of gravel is worked away by hydraulic sluicing. When the excavation has been so much enlarged that the shifting of the dredge is desirable, this is effected by letting in the water and floating the pontoon to the most convenient position for continuing the work.

The pump-dredge has several advantages which make it more efficient than a bucket dredge under certain conditions. Thus, where the bed-rock, or "bottom," consists of hard and uneven rock, it would be impossible to obtain the gold lodging in the crevices by means of buckets; whereas no special difficulties would be experienced in such cases with the so-called pump-dredge. Again, where a deposit of gravel exceeds, say, fifty feet in depth, it is doubtful whether it would be practicable to work it with buckets; whereas there would be nothing to prevent its being successfully dealt with by the method of hydraulic sluicing and elevating.

When the question of cost, however, is considered, the comparison is all in favour of bucket dredges, which can be worked by two men per shift of eight hours; whereas the pump dredges require eight men per shift. Moreover as much more powerful engines are necessary for the pump dredges the consumption of fuel with these is much greater than with the bucket dredges.

Finally, it may be said that in the case of deposits of auriferous river gravels of moderate depth, resting upon fairly soft bed-rock, the bucket dredge is unquestionably the cheapest and most efficient appliance for recovering the gold; but where the deposits are of great depth, or the bed-rock is too hard and uneven to allow of the employment of bucket dredges, the process known as pump-dredging can be successfully employed, provided the gravels be sufficiently rich to cover the extra cost.

The Federal Centrifugal Gold-sluicing Company have recently completed a pnmp-dredging plant on their mine at Jembaicumbene, near Braidwood. The pontoon is forty-seven feet long, thirty-nine feet wide, and five feet deep; it rests on the bottom of the excavation when in operation, but can be floated when it is desired to move it. The engine is a horizontal compound one, of 300 horse-power indicated, with cylinders of eighteen and thirty inches diameter, and with a thirty-three-inch stroke. Steam is supplied by three boilers seven feet six inches in diameter by fourteen feet long. The flues are fifty feet high by twenty-six inches diameter. There are two centrifugal pumps of the Kershaw type, each with a twelve-inch delivery pipe, the runners and casing being fitted with removable liners. Each pump is driven independently by rope gearing from the crank shaft of the engine. One of the pumps is used for working the hydraulic giant nozzles, while the other elevates the water and gravel to the sluice boxes, which are forty-five feet long, and are fixed on a trestle-work erected on the pontoon. The engine is sufficiently powerful to drive much larger pumps if desired.

### *Nuggets, or Large Masses of Detrital Gold.*

The Colony of Victoria has produced not only the two largest nuggets yet found in Australia, but many others of considerable size. The two largest Victorian nuggets were the "Welcome Stranger" (found at Mount Moliagul, near Dunolly), weighing over 2,280 ounces, and the "Welcome Nugget" (found at Ballarat), weighing 2,217 ounces, 16 pennyweights, and at least two others have been found

*Photographed by E. F. Pittman.*

THE FEDERAL CENTRIFUGAL PUMP DREDGE, JEMBAICUMBENE, NEAR BRAIDWOOD.

exceeding 1,600 ounces in weight. The largest nugget ever found in New South Wales was from Burrandong, near Orange, and weighed 1,286 ounces 8 pennyweights. The origin of nuggets is a matter which has excited a considerable amount of controversy. The generally accepted theory is that they represent rich portions of gold-bearing reefs, or veins, and that, having been set free from their matrix by atmospheric denudation, they have been subsequently carried to other (lower) positions, sometimes far removed from the parent reef, by the action of running water. All nuggets of any great size which have hitherto been found have had some quartz adhering to them, and this fact is, in itself, strong evidence in favour of their being detrital in their origin. Mr. A. R. C. Selwyn, the late Director of the Geological Survey of Victoria, was the first to advance the theory that nuggets may have been formed in the drifts in which they are found, or, in other words, that they may have *grown* through successive depositions of metallic gold from waters carrying gold in solution, and circulating through the alluvials. This theory was subsequently upheld by Messrs. Daintree, Wilkinson, and Newbery, the former of whom discovered that gold is deposited from a solution of its chloride in the presence of organic matter. It was pointed out that there is sufficient organic matter, in the form of wood, in the alluvial *leads* to effect the reduction of the gold in this way, though it was discovered later by Skey, of New Zealand, that various sulphides and arsenides, such as pyrites, galena, mispickel, &c., will bring about the deposition of gold from solutions in the absence of organic matter. The advocates of the theory of "growth" held that the presence of a comparatively small quantity of quartz in a large nugget did not necessarily prove that the whole nugget had been derived from a reef, but that probably a portion only, with quartz attached, had been thus derived, and had formed a nucleus, upon which a quantity of gold had afterwards been deposited from solution. They pointed out that such large masses of solid gold as the Welcome Stranger, the Welcome Nugget, and several others, had never been discovered *in situ* in a lode, and, moreover, that it was extremely difficult to believe that masses of such high specific gravity could, if derived from lodes, have been transported to the positions in which they were found by the agency of running water. They were of opinion that gold probably exists, in solution, in some of the waters percolating the drifts; but it is a very difficult matter to prove this, as, if present, the gold would probably occur in extremely small proportions. In connection with this question, it may be mentioned that minute octahedral crystals of gold are distributed through the "pug," or stiff auriferous clay, from the Kanowna deep *leads*, Western Australia. The edges of these crystals are quite sharp—that is to say, they exhibit absolutely no signs of abrasion; so that their occurrence is favourable to the supposition that they have crystallised *in situ* from solutions; and if this view be accepted, it is fair to assume that some nuggets may have received additions to their bulk by the deposition of gold from solution.

## 2. Auriferous Reefs or Lodes.

*Present State of the Quartz Mining Industry.*—Although auriferous reefs are plentiful enough in the older rocks of New South Wales, quartz mining, as it is termed, has certainly not been so vigorously or successfully carried out here as in either of the adjoining colonies of Victoria or Queensland. The fact cannot be ignored that at the present day there is only one gold-mine in New South Wales with a shaft exceeding 1,000 feet in depth; whereas in Victoria one company has reached a depth of 3,352 feet, six mines are over 3,000 feet, and twelve are over 2,700 feet in depth. Nor can it be said that the poverty of the lodes is the reason for our want of enterprise; the productiveness, near the surface, of some of our best known reefs has probably never been exceeded in any part of the world, and it is unreasonable to assume that payable gold will not be found below, until a fair attempt has been made to open more of the mines to a depth.

The explanation of the unsatisfactory state of the quartz-mining industry here must be sought in the methods by which the mines are worked, rather than in the poverty of the deposits themselves. As a general rule the gold occurs in *chutes*—that is to say, that portions of the lodes containing productive ore alternate with unproductive or barren patches, and the distance separating two rich *chutes* may be considerable, whether measured horizontally or vertically. It is obvious, therefore, that in order to successfully work these deposits, such a reserve fund is required, as will enable the miner to carry out the necessary amount of *dead work*, or, in other words, to sink through the unproductive portions, and prove the position of the next productive *chute*; in short, what is required in New South Wales, is the application of the golden rule in mining, that "the exploratory shafts and drives should always be kept *well in advance* of the stopes." What actually happens is that the miner spends the golds as he wins it, and when the *chute* has been worked out, and a barren zone of quartz encountered, he has not the funds to enable him to proceed, and abandons the mine to look for some new reef that may give promise of an immediate return for his labour. In the case of companies the same result has followed, in a number of instances, owing to the disproportion between the amount of the "nominal" and that of the actual working capital. It is not an uncommon thing to see a mine started with a working capital of a few thousand pounds, from the expenditure of which it is expected to provide interest on a nominal capital of perhaps two hundred thousand. Such enterprises are, of course, foredoomed to failure, unless the deposit to be worked should be a phenomenal one. That such methods are the cause of the quartz-mining industry occupying a worse position than it should in New South Wales, is proved by the number of abandoned and comparatively shallow shafts on our gold-fields, for, in a large majority of instances, good gold has been obtained in the upper workings.

Auriferous reefs are numerous in the Silurian and Carboniferous rocks. They probably occur, also, in Devonian sediments; but this cannot be stated with certainty, as many areas which were formerly regarded as Devonian have now, on palæontological evidence, been proved to be of Carboniferous age.

In order to avoid misapprehension, it may be explained that the term "Carboniferous" is used to designate a series of rocks which, while they have the same geological age as the Carboniferous rocks of Great Britain, are very different in character from the last mentioned. The term is misleading, because the Carboniferous rocks of New South Wales are not coal-bearing, except in one district, and even there the seams are of no value. The only workable seams of coal in this colony occur in the *Permo-Carboniferous* formation, aud the *so-called* Carboniferous rocks consist, for the most part, of dark blne and grey flinty claystones, generally inclined at a high angle, and intersected by auriferous quartz veins, and other metalliferous lodes. (*Vide* tabulated statement of geological formations, page vi).

*Minerals associated with Gold in Reefs.*—The principal constituent of the gangue, or veinstuff, of auriferous lodes is quartz; calcite is often present, and barytes and fluor-spar are also met with occasionally. In the Hawkins' Hill veins (Hill End), the gold, where richest, was associated with potash mica (muscovite) instead of quartz. Limonite, resulting from the decomposition of iron pyrites, malachite, azurite, and cuprite are found in the oxidised portions of auriferous quartz reefs. Below the water line, the gold is frequently associated with either iron pyrites or mispickel, and sometimes with galena, copper pyrites, zinc blende, pyrrhotine, and stibnite. Sometimes the gold occurs in fragments and films through the solid quartz, but it is more often seen, in the upper portions of reefs, in the cavities left by the decomposition of pyrites. Below the water level the gold is found both in the free state and in the pyrites.

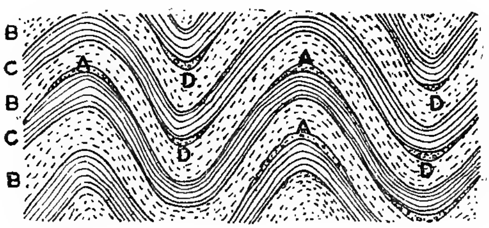
Iron pyrites, occurring in quartz reefs, is never absolutely free from gold, though sometimes it contains only a trace. Occasionally pyrites, in which no gold is visible, will yield by assay at the rate of over 100 ounces per ton. It has been held, by some geologists, that the gold, in such cases, is present as a sulphide, in combination with the pyrites, This is an assertion which it is very hard to prove or disprove, on account of the difficulty of decomposing the pyrites without also decomposing any sulphide of gold which may be present. It appears more probable, however, that the gold is present in the metallic state, aud that it is mechanically mixed with the pyrites, for, on breaking a crystal of arsenical pyrites (mispickel), it is not an uncommon thing to see fragments of gold in the centre of it; and again, if very rich iron pyrites be decomposed by nitric acid, the gold may be seen in the residue, with the aid of a microscope, in bright metallic particles of fair size; whereas a blackish-brown powder might be expected if the gold were originally present as a sulphide. Moreover, gold can always be extracted, though not completely, from finely ground auriferous pyrites, by amalgamation with mercury, and the finer the state of division of the pyrites, the greater the proportion of gold that can be extracted in this way.

*Auriferous Quartz Veins.*—Gold-bearing quartz veins occur as *Fissure Veins*, *Bedded Veins*, and *Contact Veins.*

*Fissure Veins* are those in which the quartz (with gold and other associated minerals) occupies the space between the walls of a fissure, cutting across the bedding planes of the enclosing sedimentary rocks, or intersecting such igneous rocks as granite, felspar-porphyry, diorite, etc. Veins of this description have been worked in many of our gold-fields, such as Temora, Copeland, Grenfell, Wyalong, Adelong, Parkes, etc. Their strike varies greatly, not only in widely separated fields, but in the same district. The angle of dip is also very variable. At Wyalong, and many other gold-fields, the veins are lenticular in character, varying from a mere thread to four feet in width.

*Bedded Veins* are those which occupy spaces between the planes of stratification of the enclosing rocks; they, therefore, dip with the strata. They are found in the Silurian and Carboniferous formations, and, in the former, they frequently have a meridional strike, while, owing to the great amount of disturbance which these rocks have been subjected to, they generally dip at a high angle. Veins of this class are, perhaps, more frequently met with in this Colony than either fissure veins or contact veins, and they occur in nearly all the gold-fields.

The peculiar variety of bedded veins known as saddle-reefs, and which form so marked a feature of the celebrated Bendigo gold-field in Victoria, have been worked at Hargraves, between Hill End and Mudgee. Saddle-reefs can only occur where the strata have been much contorted, so that they are arranged in a series of anticlines and synclines, or arches and troughs.




A.—Saddle reefs.
B.—Sandstone.
C.—Slate.
D.—Inverted saddles.

The folding of the rocks in this manner has caused V-shaped spaces to occur between adjoining beds at the apices of the anticlines (and also at the bases of the synclines), and the subsequent filling in of these spaces with quartz, has formed what are termed saddle-reefs.

The legs or flaps of the saddle thin out and disappear as they are followed down, but other saddles are generally found more or less perpendicularly below the first.

*Contact Veins* have been deposited along the planes of contact of two dissimilar rocks, and are frequently seen at the junction of slate with granite, or of slate with felspar-porphyry. In such cases the quartz has probably filled a contraction fissure, due to the shrinkage of the igneous rock on cooling. Many examples of these are to be found in various parts of the Colony, one of the most notable being in the Gundagai district.

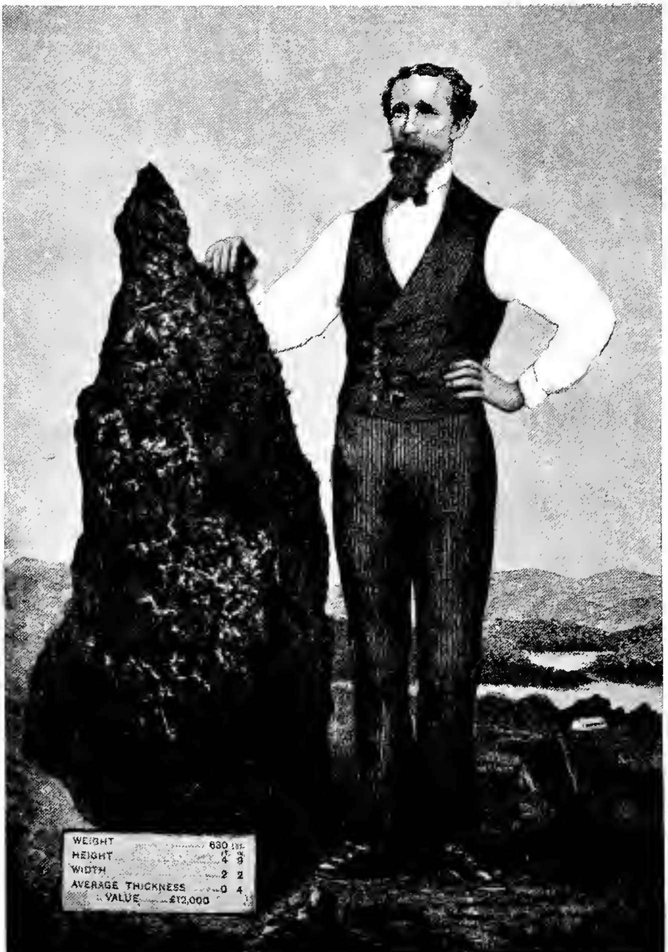
*The occurrence of large masses of Gold in Lodes.*—If it be true that all alluvial nuggets owe their origin simply to the denudation of auriferous quartz reefs, and that they have not increased in size since they were deposited in the drifts, it is natural to expect that masses of gold, as large as, or even larger than, the "Welcome Nugget" or the "Welcome Stranger" should be found *in situ* in lodes. There are no records of any such masses having been found in Victoria or Queensland, and although, in New South Wales, two extraordinary masses have been found in reefs only about twenty miles apart, it is extremely doubtful whether the largest of them could, under the influence of denudation, have furnished a nugget of the thickness and weight of either of those just mentioned.

The first of these masses was discovered at Hargraves, and received the name of "Kerr's Hundredweight." An account of the interesting find was published in the *Sydney Morning Herald*, of the 18th July, 1851, and the following is an extract from it:—"A few days ago an educated aboriginal, formerly attached to the Wellington Mission, and who had been in the service of Dr. W. J. Kerr, of Wallawa, about seven years, returned home to his employer with the intelligence that he had discovered a large mass of gold amongst a heap of quartz, upon the run, whilst tending his sheep. Gold being the universal topic of conversation, the curiosity of this sable son of the forest was excited, and, provided with a tomahawk, he had amused himself by exploring the country adjacent to his employer's land, and had thus made the discovery. His attention was first called to the lucky spot by observing a speck of some glittering, yellow substance upon the surface of a block of quartz, upon which he applied his tomahawk, and broke off a portion—at that moment the splendid prize stood revealed to his sight. His first care was to start off home and disclose his discovery to his master, to whom he presented whatever gold might be procured from it. As might be supposed, little time was lost by the worthy doctor. Quick as horse-flesh would carry him, he was on the ground, and, in a very short period, the three blocks of quartz, containing the hundredweight of gold, were released from the bed, where, charged with unknown wealth, they had rested, perhaps, for thousands of years, awaiting the hand of civilised man to disturb them. The largest of the blocks was about a foot in diameter, and weighed seventy-five pounds gross. Out of this piece, 60 lbs. of pure gold was taken. Before separation, it was beautifully encased in quartz. The other two were something smaller. . . . Not being able to move it conveniently, Dr. Kerr broke the pieces into small fragments, and herein committed a very grand error—as specimens, the glittering blocks would have been invaluable." It was afterwards found that the total weight of the gold was 106 pounds. Dr. Kerr retained upwards of three pounds as specimens, and these are understood to be now in the possession of the Honorable W. H. Suttor, M.L.C.

The discovery of the second and largest mass of gold ever recorded, was made in Beyers and Holtermann's claim, at Hill End, in 1872. As this was probably the largest mass of gold ever found in any part of the world, the particulars in regard to it are worthy of record. The discovery was alluded to in the public Press of the day, and the following account of it is taken from the *Sydney Morning Herald*, of Monday, the 4th November, 1872:—

"There has been another large yield of gold in one of the wonderful Hill End Mines—Messrs. Beyers and Holtermann's claim. Our correspondent chronicles the event:—'On Friday night last the largest and richest specimen this Colony has produced, I suppose, was taken from the claim of Beyers and Holtermann. It is really a wonderful one—a slab of gold. Its weight is about 6½ cwt.; and I believe I am within the mark in saying that there are 2 cwt. of gold in it. I went, together with nearly the whole town, to look at it. The claim was like a fair, and a regular stream of people threaded the steep packing tracks leading down to it. On Sunday it was hung up for exhibition, and during the day hundreds, including many of the fair sex, went down to see it. At the same time that I went down to look at this, Mr. Bullock, the Manager, kindly revealed the treasures of the iron box, in which are specimens, not so large, certainly, but prettier to look upon. The monster is not alone in his glory; he has fellows bigger and richer below, I am told. He appears to form part of a lode rather than a vein, as no quartz seems to be showing—nothing but mundic and a slate casing.'"

"In a subsequent communication our correspondent again wrote respecting this claim:—'The all-absorbing topic of conversation is the result of Beyers and Holtermann's crushing. The estimated yield is between ten and twelve thousand ounces. The amount of amalgam, hard squeezed, and probably nearly two-thirds gold, is about eight hundredweight, irrespective of the monster specimen, and those raised since its appearance. About six hundredweight of amalgam is now being retorted, leaving two hundredweight to be operated upon. The nugget goes through to-morrow, and a considerable quantity of stone, together with specimens, remains to go through. On Wednesday I went over the claim to see principally what was to come, as there was talk of another monster, bigger than the first; and certainly there was every reason to expect one; over seven feet of what looked like a bar of gold lay glittering along the stope. On Friday this was taken down, but broke in the operation; so that, although extremely rich, it




HOLTERMAN'S NUGGET.

The largest mass of gold ever found. Extracted in 1872 from a lode in Beyers and Holterman's claim, Hill End.

did not equal its predecessor in size. Gold can be seen all through the claim, and another crosscut, at a level considerably below the present rich workings, put through them to the West, has discovered another batch of veins calculated to go 6 ounces. The wealth of the claim is great, and requires to be seen to be believed.' "

According to subsequent issues of the same paper, the result of this crushing of Beyers and Holtermann's was that 400 tons of stone yielded 15,600 ounces of gold, or at the rate of thirty-nine ounces per ton. The value of the yield was over £60,000, and a dividend of fifteen shillings per share, equal to seventy-five per cent. of the capital of the Company, was declared.

The late Mr. Holtermann, one of the principal shareholders in the Company, had a photograph taken of the mass of gold shortly before it was broken up. In this photograph he was represented standing beside the specimen, so as to convey an idea of its height as compared with that of a man. He afterwards had a wood-cut prepared from the photograph, and he used this as an advertisement for some patent medicines in which he was interested.

The accompanying photograph is taken from the wood-cut referred to, and upon it are recorded the dimensions and value of the block of golden stone. The total weight was 630 pounds. It was four feet nine inches in height, two feet two inches in width, and its average thickness was four inches. The value was put down as £12,000, which would represent 3,000 ounces, but this is evidently an approximation, as the specimen was treated with a quantity of other stone, and the exact amount of gold could not have been determined. Mr. H. L. Beyers, however, states that they refused an offer of £13,000 for the specimen when it was first found.

It would not be feasible, in a small work like this, to attempt a description of all the gold fields in which auriferous quartz reefs are worked, nor is it necessary, in view of the fact that a detailed description of each field, accompanied by a geological map, will be published by the Department of Mines in the near future. It is proposed, however, to briefly refer here to a few of the best known fields where typical deposits occur.

*The Hill End Gold-field.*—Hill End is situated about thirty miles North by West from Bathurst, but, owing to the rough nature of the intervening country, the journey by road covers a distance of more than fifty miles. Rich deposits of alluvial gold were obtained at Hill End and Tambaroora in the early days of gold-mining, but the reefs did not attract much attention until 1872, when enormously rich deposits were found in Hawkins' Hill. The rocks of the Hill End gold-field consist of dark fissile slates, flinty altered claystones, and interbedded volcanic tuffs, containing waterworn pebbles, and fairly well preserved crinoid stems, and other fossil organic remains. The age of these beds is regarded as Upper Silurian. The strata have been very much disturbed by intrusions of quartz porphyry from the west, which have tilted the beds into a huge anticline or acute arch, the axis of which runs in a north and south direction through the centre of the gold-field. Sills of quartz porphyry have also intruded the sedimentary strata. The auriferous reefs are either included in the narrow beds of black slate, or occur at the junction between the slate and a sill, or a bed of volcanic tuff. They therefore belong to the variety of veins known as bedded veins. They are also somewhat lenticular in character, their width varying from a fraction of an inch up to several feet. By far the richest reefs have been found on the eastern side of the anticline, where the dip of the strata is also east, at an angle of about 55°. These Hawkins' Hill veins, in which the extremely rich deposits of gold were found in the year 1872, possess some special features of interest. They consist of a series of nine or ten narrow veins, rarely more than a few inches in thickness, and having an easterly dip which averages about 55°. They occur in very narrow beds of black slate, but sometimes followed the line of junction between the slate and an adjoining bed or sill. They have frequently been faulted by *slides* which come in from the hanging wall; the extent of throw is generally about equal to the width of the vein. Where the richest gold was obtained, the quartz, which generally forms the gangue or veinstone on this field, was almost entirely replaced by a silvery white mica (muscovite). The richness of these lodes was phenomenal, and where good gold was found in one of them, the others of the series were also found to be enriched. The gold occurred in *chutes* which dipped to the south, along the course of the veins. A number of claims yielded rich returns on Hawkins' Hill while the *chutes* lasted, and were worked to depths of from 400 feet to 700 feet, but when poorer stone was encountered active operations ceased. A tunnel put into the hill more recently has intersected the series of veins at a lower level, and here they are found to have preserved their general size and character, except that the gangue is now composed of quartz, and the gold contents are not so high.

Probably no other field in New South Wales offers such legitimate inducements for the investment of capital as Hawkins' Hill. It is true that comparatively barren stone has succeeded the extraordinarily rich ore which was worked in 1872; but this is only what must be expected in all mines where gold occurs in *chutes*. What is required is systematic prospecting, at greater depths, for a recurrence of the rich deposits; and it is extraordinary that such a length of time has been allowed to elapse without any attempt to carry out this prospecting. It is inaction like this which is responsible for the statements, which are heard from time to time, to the effect that the auriferous reefs of New South Wales are not productive at a depth. Such statements are unjustifiable, because the instances where any attempt at deep prospecting has been made can be numbered on the fingers of one hand; and seeing that the deepest shaft in any New South Wales gold-mine, at the present time, is only 1,140 feet, it is premature to assume that our auriferous deposits do not extend as deep as those of Queensland on the north, or of Victoria on the south. There are no geological reasons why they should not be payable in depth, and the evidence available in the Hillgrove mines (which has a more direct bearing on the question than that supplied by any of our other gold-fields) is decidedly in favour of the gold extending to considerable depths.

It is understood that there is a probability of an English Company being formed to test the Hill End veins at a depth of 1,400 feet, by driving a long tunnel along the course of the veins, from the foot of Hawkins' Hill. There is no doubt that this would be the most satisfactory method of prospecting the deposits.

Some years after the Hawkins' Hill veins yielded their rich returns, a cross reef, striking east and west, was discovered about a quarter of a mile further north. It was found that this reef faulted the Hawkins' Hill veins, the throw being to the west, and amounting to sixty or seventy feet. As the veins approached the cross-course they were curved or deflected from their course, and, on the northern side of the cross-course, they followed similar curves for some distance before again resuming their normal strike, in the direction of Tambaroora. The cross reef was worked, in Emmett and Hughes' Mine, down to the water level. Some extremely rich returns were obtained in the oxidised zone, but below that the lode was heavily charged with massive arsenical pyrites (mispickel), containing a very high percentage of gold. Crystals of mispickel were obtained fully an inch and a half in length, and coarse fragments of free gold were not uncommonly seen in the solid mispickel, or protruding from the faces of the crystals. The owners of the mine, however, failed in their efforts to extract the gold from the ore at a profit, and the mine has now been idle for some years. This ore is interesting as being the only occurrence of massive arsenical pyrites on the field, and there is very little doubt that it will yet be successfully worked.

*The Hargraves Gold-field.*—This field was one of the first to be discovered, for it was in July, 1851, that the celebrated "Kerr's Hundredweight" (a mass of gold weighing 106 pounds, and already alluded to on page 29) was found, by an aboriginal shepherd, in the outcrop of a quartz reef close to the present village of Hargraves. Immediately afterwards a "rush" took place to the locality, and extremely rich alluvial deposits were discovered. For a considerable period between 4,000 and 5,000 ounces of gold are said to have been sent away from the field every fortnight under police escort. Unfortunately the exact returns for the first few years after the discovery are not available; but even after the greater portion of the easily won gold had been extracted, and the bulk of the mining population had left the district, good yields were obtained from this field; thus, in 1858, seven years after its discovery, 40,685 ounces were won, and from 1858 to 1874, inclusive, 205,585 ounces were obtained, being equivalent to an average annual yield of 12,093 ounces for seventeen successive years.

In the meantime the reefs, or the sources whence these enormous supplies of alluvial gold were derived, have been worked in a desultory kind of way for nearly fifty years; yet, notwithstanding the strong presumptive evidence of their productiveness, furnished by the rich detrital deposits just alluded to, the fact remains that at the end of the year 1899 the two deepest shafts on the field were only 213 feet and 198 feet respectively. The reasons given, locally, for this remarkable want of enterprise are—(1) that the rich gold is patchy, and (2) that heavy water is met with at a depth of sixty or seventy feet; in short, Hargraves affords a good example of the methods by which the gold-mining industry is carried on in many parts of New South Wales. It is improbable that similar deposits would be allowed to remain unprospected in depth in any other English-speaking country.

The geology of Hargraves is almost identical with that of Hill End, in fact the first-named field is situated (about twenty miles farther north) on the same belt of rocks as the latter. The auriferous reefs occur in fissile slates and indurated claystones of Upper Silurian age, intercalated with beds of submarine volcanic tuff containing rounded pebbles and well-preserved organic remains, such as crinoid stems. On the eastern side of the field is a large granitic dyke, and intrusive sheets or sills of granite and felsite also occur between the beds of slate, &c. The whole series of slates, claystones, tuffs, and sills has been thrown into a number of anticlinal and synclinal folds (saddles and troughs), probably by the intrusion of the igneous rocks in the neighbourhood of the field. Owing to this bending of the strata, spaces were formed between contiguous beds in the anticlines and synclines, and the subsequent filling of these spaces with auriferous quartz, deposited from hydro-thermal solutions, has produced what are termed saddle-reefs, the name having been given to them on account of their resemblance to a saddle in cross section (*vide* sketch illustrating formation of saddle-reefs on page 28). The upper and thickest portion of a saddle-reef is termed the "cap," while the "legs," which correspond with the flaps of a saddle, dip away on either side, parallel with the enclosing rocks, and gradually thin out to nothing. Although the legs of a saddle-reef are not found to maintain their width, or to extend to any considerable depth, the permanence of the mines is assured by reason of the certainty of other saddle reefs being discovered below the first, and at greater or less intervals of depth. The top of the arch or anticline of the folded rocks is termed by the miners "centre country," and if a vertical shaft be sunk through this it will be found to intersect one saddle-reef after another at irregular intervals. The reason of this will be readily understood if a quire of notepaper be laid flat upon the table, and if lateral pressure be then exerted against the sides; the bending of the paper into a series of arches will be accompanied by the formation of a number of saddle-shaped spaces, separated by greater or less vertical distances; and these will correspond with the spaces formed by the folding of the rocks at Hargraves, and now occupied by saddle-reefs.

A reef which occupies the space between two adjoining beds of a trough or syncline is termed an inverted saddle. In this case the legs commence as thin veins at their upper extremities, and gradually

*Photographed by E. F. Pittman.*

CAP OF A SADDLE REEF. BIG NUGGET HILL, HARGRAVES.

*Photographed by E. F. Pittman.*

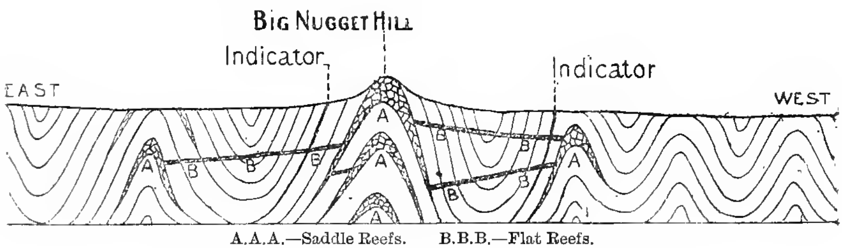
Curved Beds of Slate, &c. showing the Pitch of the "Centre Country" in which Saddle Reefs occur. Hargraves Gold-field.

converge, and at the same time increase in thickness, as they are followed down to the junction, which occupies the lowest position.

At Hargraves the main axes of the folds have a general direction of N. 20° W. and S. 20° E., which is accordingly the course or strike of the saddle-reefs. But the rocks have also been folded along axes at right-angles to those just mentioned, and as a consequence of this fact it follows that the caps of the saddle-reefs undulate; so that while they are occasionally seen outcropping at the surface, they are found to *pitch* to the north if followed along the strike in one direction, and to the south if traced the opposite way.

There are at least six distinct lines of saddle-reefs known to exist on the Hargraves Gold-field; and on what may be termed the main line, viz., Big Nugget Hill, three saddle-reefs have been proved in vertical sequence. The first reef outcrops at the surface, where its cap has a width of nearly ten feet; the second was found below this at a depth of twenty feet; and the third at a depth of sixty feet. There can be very little doubt that a number of other similar reefs occur at greater depths, but want of enterprise has hitherto prevented their being searched for. Inverted saddle-reefs are of rarer occurrence, but one of these is also being worked at the present time in a mine to the east of the Big Nugget Hill.

The deposits just described are identical in their mode of occurrence with those which have become celebrated at Bendigo, in Victoria, and which have been proved payable on that field to a depth of considerably over 3,000 feet from the surface, forming, in fact, the deepest gold-mines in the world. There is, moreover, every reason to believe that the saddle-reefs at Hargraves would be quite as productive as those of Bendigo if they were as systematically worked.




A.A.A.—Saddle Reefs. B.B.B.—Flat Reefs.

SECTION THROUGH BIG NUGGET HILL, HARGRAVES.

The rich gold in the Hargraves saddle-reef appears to occur in *chutes*, which, so far as can be learned from the work already done on the field, cross the reefs diagonally in an approximately north-west and south-east direction. Faults are frequently met with in the underground workings on the legs of the reefs, but as a rule the displacement caused by a fault does not exceed a foot or two. The beds of slate immediately above the caps of the saddle-reefs (centre country) usually exhibit much crushing, due to compression of the under side of the beds when the folding occurred.

Auriferous reefs of another kind, termed locally "flat reefs," also occur at Hargraves, and present some interesting features. As their name implies, they are more or less horizontal in their course, and they cut across the bedding planes of the rocks, evidently occupying fissures caused by cross strains during the folding of the strata. They are rarely more than two or three inches in thickness, and they appear to be usually connected with the leg of a saddle-reef. As a general rule the flat reefs have not been found to contain payable gold throughout, but extremely rich deposits of the precious metal occur in them along the plane of their intersection with what is locally known as a "mark" or indicator. A "mark" or indicator is a narrow band, from one to three inches wide, of dark greenish slate, enclosing a very thin vein of quartz, generally from one-eighth to half-an-inch wide. The "marks" are conformable with the ordinary country rock—that is to say, their dip and strike are the same as those of the beds of slate, claystone, and tuff which bound them—and they are generally inclined at a high angle, being nearly, but not quite, vertical. Wherever the intersection of one of these indicators with a flat vein occurs, rich specimens of gold are found in the latter, but they are always confined within a few inches of the plane of intersection. The method of prospecting followed in the past was to trench along the course of an indicator until its intersection with a flat reef was found, and long lines of old workings remain to this day to attest the success of the method, but there is no evidence to show that, when these contact deposits were worked out, any attempt was made to discover whether the indicator intersected any other flat reefs below the first. The indicators do not appear to be themselves auriferous, and the cause of the enrichment of the flat reefs along the plane of intersection is difficult to explain.

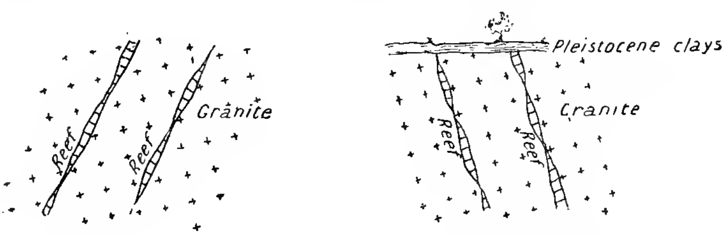
*The Wyalong Gold-field.*—Gold was first discovered at Wyalong in August 1893, and this district, therefore possesses peculiar interest as being the most recently opened gold-field in New South Wales. In addition to this it is deserving of special mention as including, at the present time, the most productive gold-bearing reefs in the Colony. The total amount of gold obtained at Wyalong from its discovery up to the end of 1899 is 181,268 ounces, valued at £712,358, and the annual yields have been as follows:—

| Year. | Tons. | Ounces. | Value. |
|---|---|---|---|
| | | | £ |
| 1894 | 6,358 | 9,649 | 35,946 |
| 1895 | 15,634 | 24,497 | 91,864 |
| 1896 | 18,279 | 33,495 | 130,000 |
| 1897 | 30,750 | 34,370 | 137,490 |
| 1898 | 30,940 | 34,582 | 138,328 |
| 1899 | | 44,675 | 178,700 |

Wyalong is situated about forty miles in a north-westerly direction from the terminus of the railway line at Temora. The country where gold was discovered consists of level plains with a few isolated low ridges. The surface of the plains consists, to a depth of two or three feet, of red and black clayey soils of Pleistocene age, with ironstone pebbles, and occasional sub-angular fragments of quartz. The low hills in the vicinity of Wyalong are formed of hard rocks, such as diorite, and hornblendic granite, or quartz diorite, with narrow belts of slate. The latter are probably of Upper Silurian age, and have been intruded by the granites and diorites.

Immediately underneath the two or three feet of Pleistocene clay, which forms the surface of the plains, decomposed granitic rocks occur. These are of various shades of grey, yellow, brown and red; and while some of them have evidently been ternary granites, others are probably decomposed felsites, and hornblendic granites, the brown and red colour being caused by the peroxide of iron resulting from the decomposition of the hornblende.

The auriferous reefs occur, for the most part, in the hornblendic granite, which has been decomposed to a depth varying from 150 to 200 feet from the surface. In consequence of this, no explosives were necessary for mining operations above the water level, and the work of excavation was easily performed with the pick and shovel. In the vicinity of the reefs the granite exhibits signs of crushing, and, generally speaking, a gneissose structure is noticeable. The reefs are of lenticular character, varying in width from a fraction of an inch up to four or five feet, and often exhibiting their maximum and minimum dimensions within a distance of twenty or thirty feet. This variation in width is a recurring feature in their horizontal course as well as in their downward extension. They are generally found, underneath the Pleistocene deposits, in the surface of the decomposed granite, where they appear as narrow threads, which widen out and again contract as they are followed down.




Plan. Vertical Section.

SKETCH SHOWING CHARACTER OF AURIFEROUS REEFS AT WYALONG.

The general strike of the reefs is about N. 20° E., and as a rule they have an easterly dip. There are about eight approximately parallel lines of reef following this course in the centre of the field, while one noticeable exception, the Pioneer Reef, strikes nearly east and west, and has a northerly dip. Inclusions of country rock, known amongst miners as "horses," are of common occurrence in these reefs, and faults are also frequently met with. Slickensides, or grooved and polished surfaces, due to movements of the walls, are often seen, and in some cases the face of the slickenside is covered with a film of gold. In the oxidised zone, small quantities of limonite, calcite, malachite, and gypsum occur, in addition to quartz and gold, and below the water level the associated minerals are iron pyrites, and mispickel, galena, zincblende, and native copper, the first named being present in by far the greatest proportion. The gold in these reefs is, as a rule, in a very fine state of division and has probably been derived from the pyrites, which is exceedingly rich in the lower levels. Occasionally the pyrites occurs in solid veins up to a foot in thickness, as in the Lucknow Mine, and this ore yields from twenty to twenty-five ounces of gold per ton. From January 1895, to October 1898, 784 tons of ore from this mine yielded 5,587 ounces of gold. The richest mines at the present time are Neeld's Prospecting Claim, the Lucknow, and the Bantam Proprietary. The deepest shaft on the field is about 500 feet. The Wyalong Gold-field was discovered by Mr. Neeld, a selector, who exhibited much intelligence and persistence in the difficult work of prospecting in such flat country, where there were practically no indications of gold on the surface. He was rewarded by finding most of the best mines on the field. No alluvial deposits have yet been discovered at Wyalong. It is unreasonable to suppose that they do not exist, but the extremely level nature of the surrounding country, and the fact that the surface is uniformly covered by a thickness of several feet of Post Tertiary clays, render it extremely difficult to locate the old drainage channels where alluvial gold might be expected to occur.

The chief difficulty in connection with gold-mining at Wyalong is the scarcity of water. The average rainfall is about twenty inches, but the district has suffered severely from droughts since gold was discovered there, and, owing to the flat nature of the country, it is not easy to conserve water. In consequence of this it has been necessary to suspend crushing operations for considerable periods.

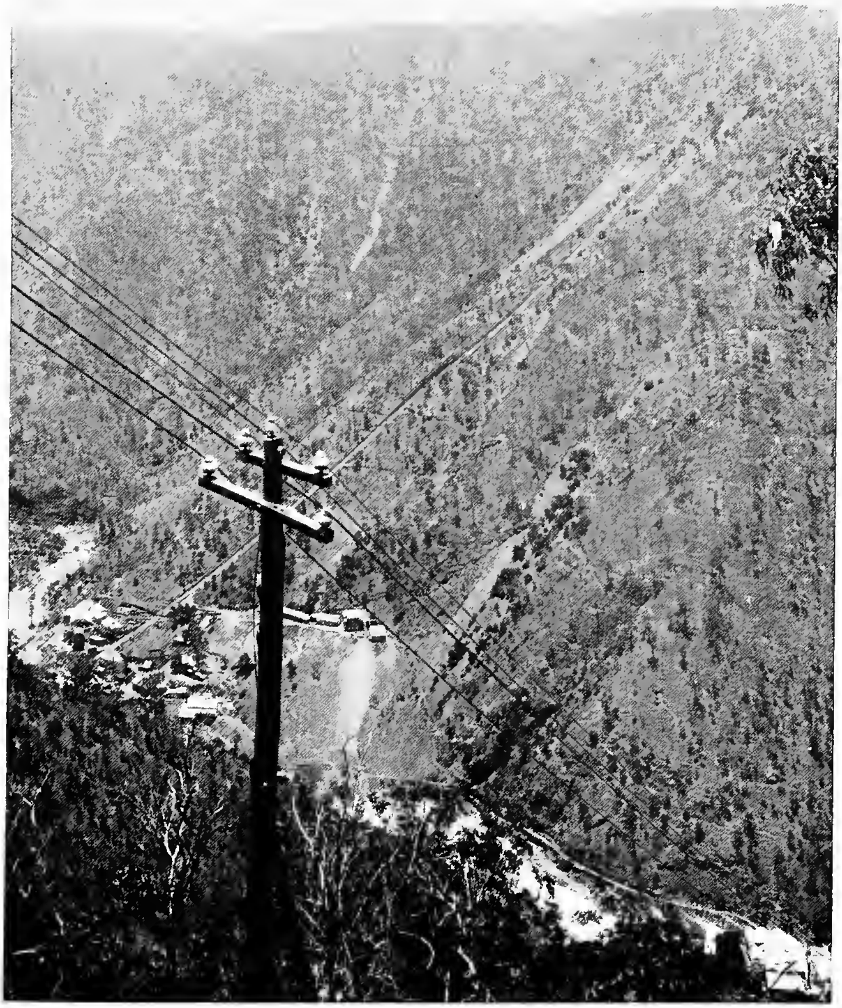
*The Hillgrove Gold-field.*—This field is of special interest on account of its containing quartz reefs in which gold is associated with stibnite, or sulphide of antimony. Hillgrove is situated on Baker's Creek, in very rough country about twenty miles to the east of Armidale. The reefs occur for the most part in highly altered blue claystones near their junction with a large *massif* of intrusive granite, and dykes of granite also intrude the claystones in the vicinity of the productive lodes. No fossils have as yet been found in the claystones, but, judging by their lithological characters, it is probable that they are of Carboniferous age. The veinstone in many of the Hillgrove reefs has a very characteristic brecciated appearance, owing to the presence in it of angular fragments of blue claystone, which have evidently fallen into the fissures from the hanging wall during the process of filling, and which have been cemented together by quartz deposited from solution. Small lodes of stibnite are of frequent occurrence in the granite near its junction with the sedimentary rocks, and in some instances the stibnite is associated with scheelite. The deposits of the latter mineral appear to encrust the stibnite, and they vary in width from half-an-inch to four inches, though occasionally masses of scheelite one foot in thickness are found.

The principal mines in the Hillgrove field are the Eleanora Gold and Antimony Mining Co., the Baker's Creek Gold-mining Co., the Baker's Creek Consols Gold-mining Co., the Sunlight Gold-mining Co., the Hillgrove Proprietary Mines, the Garibaldi Gold-mining Co., the Hopetoun Gold-mining Co., the Cosmopolitan Gold-mining Co., and the Carrington Gold-mining Co. At the present time only the first five of these mines are working.

The *Eleanora* Reef, which is the largest on the field, accompanies an intrusive dyke, and has formed on both sides of the latter. Both the dyke and the reef vary in thickness—the former from one to five feet, and the latter from six inches to as much as twenty feet; the average width of the reef may be put down at six feet. Sulphide (and in the upper levels, oxide) of antimony occurs in irregular bunches, and is also disseminated through the reef in places; iron pyrites and marcasite are also present in the veinstone. Free gold is sometimes visible in the quartz, and the stibnite and other sulphides also carry both gold and silver, the former varying from a trace up to several ounces per ton, and the latter from a trace up to one ounce. The working of this deposit has not been so successful as could be desired, owing to the difficulty of recovering the gold in the presence of the antimony. The average yield is six and a half pennyweights of free gold per ton, and gold at the rate of two and a half pennyweights per ton of ore is also recovered from the concentrates, making a total recovery of nine pennyweights per ton. There are two shafts down to a depth of 600 feet each, and connected by drives. The proportion of stibnite in the ore appears to be decreasing in the lower levels; at present it amounts to about three per cent. The presence of so much stibnite rendered the extraction of the free gold by amalgamation very difficult in the earlier years of the mine's history, as it had a tendency to sicken the mercury, and consequently the use of copper plates was abandoned, and the pulverised ore was run over blanket tables. At the present time, owing to the smaller quantity of stibnite met with, one length of amalgamated copper plate is interposed between the battery boxes and the blanket tables, and this arrangement is found to work satisfactorily. The battery consists of seventy stamps, having a weight of 760 pounds each; they have a drop of nine inches, and are worked at a speed of eighty-five blows per minute, giving a duty of twenty-three hundredweight per stamp per twenty-four hours. The battery screens are of 360 mesh, and the depth of discharge is one and a half inch. Usually about 900 tons of ore are crushed per fortnight. The pulp, on issuing from the screens, passes over five feet of amalgamated copper plates, and then over about thirty-five feet of blanket tables. From these it passes over Frue vanners, of which there is one for every five head of stamps. The blanketings, collected by washing the strips of blanket in a vat of water, are treated in Berdan pans containing mercury, by which they are ground fine, while the free gold is amalgamated. From the Berdans the pulp passes into a settling pan containing agitators, where any floured mercury is collected, and it is then conducted to the Frue vanners, by which it is separated into concentrates and tailings. The concentrates are roasted in reverberatory furnaces to free them of antimony, arsenic, and sulphur, and are then sold to the Smelting Company of Australia, whose works are at Dapto. The oxide of antimony, formed during the roasting process, is condensed in flues and chambers, and is exported. Over fourteen tons of oxide of antimony have been collected in the chambers and sold during the past twelve months, but it is evident from the appearance of the fumes coming from the chimney stack, that a considerable proportion of the antimony is lost. The roasted concentrates contain, on an average, about three and a half ounces of gold per ton. The tailings assay at the rate of six pennyweights per ton, and there is a considerable accumulation of these at the mine; but, on account of the quality of the antimony which they contain, their economical treatment is a problem which yet remains to be solved.

From July, 1892, to June, 1899, this mine has produced 67,947 tons of ore, which have yielded 29,730 ounces of free gold, and 2,036½ tons of concentrates, containing on an average three and a half ounces of gold per ton. In addition to this, there has been produced, during the same period, 1,092 tons of crude antimony, and eighty-five tons of white metal.

*Baker's Creek Gold-mining Co.*—In this company's mine four small reefs have been worked. The two principal ones are known as *Smith's Reef*, and the *Big Reef*, though the latter is somewhat of a misnomer. The four reefs vary from a mere thread up to eighteen inches in width, the average being about six inches; and they are, as a rule, most productive in their narrower portions. Smith's Reef, which was named after its discoverer, and which was the first to be found, has been exceedingly rich, the earlier crushings yielding at the rate of ten ounces of gold per ton. The strike of this reef is about N. 55° W., and its dip is N. 35° E. at an angle of about 75°. Its outcrop was upon the side of the deep gorge of Baker's Creek, at a height of about 330 feet above the creek bed. The battery is situated just above the latter, and a double tramway has been constructed in a straight line down the steep side of the gorge from the tableland on top, where the Eleanora Mine is situated, to the Baker's Creek battery at the bottom. The difference in altitude between the two termini of the tramway is



*Photographed by E. F. Pittman.*

BAKER'S CREEK GORGE, HILLGROVE.—THE BAKER'S CREEK G. M. COMPANY'S TRAMWAY.

1,407 feet, and the horizontal distance between them is 2,240 feet. The average inclination of the tramway is, therefore, rather more than 32°. The total depth of the workings in the Baker's Creek Mine is 1,300 feet from the outcrop, and the main (inclined) shaft, which starts from near the level of the creek, is down 1,000 feet.

The battery includes fifty head of stamps, weighing 680 pounds each; of these, only forty head are in the main building, the remaining ten head having originally belonged to the Baker's Creek North Mine. The stamps work at a speed of ninety-five blows per minute, with a drop of six to seven inches, and the depth of discharge is five inches. The stamp duty is eighteen hundredweight. At the present time about 530 tons of ore per fortnight are crushed by forty head of stamps. Automatic feeders are used. The pulp as it leaves the screens passes over amalgamated copper plates, and then over blanket-tables; the tailings pass through spitzkasten, and the concentrates are treated on Woodbury vanners. The blanketings (obtained by rinsing the blankets at intervals in a vat of water) are first treated in revolving barrels with mercury, to collect the free gold, and are then emptied into Berdan pans, where they are ground fine with mercury. From here they pass over an end-throw percussion table, and finally the concentrates from the latter are dried and sent to the Wallaroo Smelting Works in South Australia. At present the ore contains an average of about eighteen pennyweights of free gold per ton, and about one per cent. of concentrates are saved, which yield about five ounces of gold per ton. The Baker's Creek ore has never contained as much stibnite as that from the Eleanora Mine. A certain amount of it, however, is present, in bunches, as is also iron pyrites, but no mispickel. The tailings from this mine are said to contain only two pennyweights of gold per ton. The Baker's Creek Mine has been a remarkably profitable one for its shareholders. From the 12th November, 1887 (the date of the first crushing), to the 27th October, 1899, the ore crushed amounted to 115,463 tons, and the total yield was 186,044 ounces of free gold. This does not include the gold obtained by the treatment of the concentrates. The sum of £267,000 has been paid in dividends during the same period. It may be mentioned that the gold from the Hillgrove mines varies in value from £3 10s. to £3 15s. per ounce, the average value being about £3 12s.

*The Sunlight Gold-mining Co.*—The Sunlight Mine is situated on the western side of the gorge, or on the opposite side to the mine last described, and it is also provided with an inclined tramway, reaching from the top of the western tableland to the battery, which has been constructed on the bed of Baker's Creek. The Sunlight Reef varies from six inches to four feet in width, its average width being about two feet; it contains free gold and a little stibnite, iron pyrites, and mispickel. The free gold amounts to about nine pennyweights per ton, and about one per cent. of concentrates are saved, which contain on an average seven ounces of gold per ton.

The workings have reached a depth of 900 feet from the outcrop, which is on the side of the gorge. Five tunnels have been driven to the reef from the side of the gorge, and these are connected with one another, and with three levels below them, by the main winze.

The battery contains forty head of stamps, weighing 600 pounds each, and these are worked at a speed of seventy-five blows per minute, with a drop of eight inches. The depth of discharge is three inches; the screens are 260 mesh. The stamp duty is from eighteen to twenty hundredweight. The pulp as it leaves the battery flows over electro-plated copper-plates, and thence over eight Frue vanners. The concentrates are dried and sold to the Dapto Smelting Works. They contain 5·2 per cent. of antimony and 13·9 per cent. of arsenic. The mine is lighted throughout by electricity.

From the 1st January, 1892, to the 18th October, 1899, the Sunlight Mine has produced 73,155 tons of ore, yielding 36,217 ounces of gold. The highest yield of any crushing was at the rate of twenty-three pennyweights per ton.

*The Hillgrove Proprietary Mines.*—The operations in this mine have, up to the present, been confined to prospecting. The land held by the company lies to the south-east of the Baker's Creek Mine, and a considerable amount of money has been expended in efforts to trace the continuation of the rich auriferous *chutes* of the Baker's Creek reefs. Up to the end of October, 1899, a tunnel had been driven into the side of the gorge for a distance of nearly 1,800 feet, in a direction at right-angles to the strike of the reefs. It is intended to continue this tunnel for a total length of 2,000 feet, and also to sink an inclined shaft from the floor of the level.*

The tramways down the steep sides of the gorge of Baker's Creek are necessary, not only for the conveyance of the men to their work, but also for bringing the supply of firewood to the battery engines. Firewood is at present a very expensive item in the cost of working the Hillgrove mines, but it is probable that it will very soon be dispensed with, for advantage is being taken of the natural facilities of the country for the supply of hydraulic and electric power to the mines. The Sandon County Electric-light and Power Company have constructed a large dam near the Gara River Falls, about six miles from Hillgrove. The retaining-wall is formed of log-cribbing, the interstices being packed with gravel and clay, and the dam has a capacity of 300,000,000 gallons. A head of 450 feet is obtained, and the water under this pressure is used to drive Pelton wheels, each of which is capable of developing 300 horse-power. Allowing for a loss of 20 per cent. of electric-power, the company will have 1,000 horse-power available for lighting the town and driving the batteries, &c., at Hillgrove.

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* Since the above was written it was reported that the continuation of the Baker's Creek reef has been met with in these workings.

*Photographed by E. F. Pittman.*

BAKER'S CREEK GORGE HILLGROVE.

The Sunlight G. M. Company's Battery.

*Photographed by E. F. Pittman.*

THE WENTWORTH GOLD-FIELDS PROPRIETARY CO.'S MINES, LUCKNOW, NEAR ORANGE.

*The auriferous deposits of Lucknow.*—The rich auriferous deposits which have been worked in the Wentworth group of mines at Lucknow, about six miles from the town of Orange, on the Great Western Railway, are unique, both in their mode of occurrence and in regard to the character and appearance of the ore; so characteristic, indeed, is the latter, that it can be distinguished, almost at a glance, from any other auriferous ore in Australia.

Alluvial gold was first found at this locality about the year 1863, when a shallow (Pleistocene) deposit of considerable richness was worked. Subsequently a Tertiary (Pliocene) *lead* was discovered under a flow of basalt, and proved payable for a distance of about half a mile. The returns from this *lead* are said to have been from one to five ounces of gold per load.

The sources from which the detrital deposits were derived were afterwards worked in a number of claims, from which surprisingly rich yields were obtained in a very short time; thus, according to the Mining Warden's report, the claim on the Golden Point vein yielded to its shareholders £50,000 worth of gold in nine months; Spicer's vein, within a length of eighty feet, yielded £42,000 in six months; the Golden Gate vein, within a similar length, yielded £35,000 in eight months; £30,000 worth of gold was obtained in two years from the Shamrock vein, within a length of eighty feet; within a distance of twenty feet, on the Crinoline vein, £20,000 worth of the precious metal was recovered in eighteen months, and a yield of the value of £20,000 was obtained in one year from eighty feet of Snob's vein. These extremely rich deposits of gold, or "bonanzas," as they were called, were separated, both horizontally and vertically, by considerable distances of barren ground, and owing to their mode of occurrence not having been properly understood at this time, the miners failed to seek for their recurrence at a depth, and in many cases abandoned their claims when the first rich deposits were worked out.

In December, 1881, the New Reform Gold-mining Company was formed to work an area of twelve acres, containing seven of these veins. This company were successful in obtaining some exceedingly rich bonanzas, and during the years 1885-6 they paid the sum of £17,750 in dividends, after clearing off all expenses connected with the purchase of machinery, and sinking their main shaft to a depth of 400 feet. In the year 1887 the company won gold to the value of £15,326; in the following year the workings reached a depth 525 feet, and 3,000 tons of ore, valued at £6,484, were raised. In 1889 no rich deposits were found, and the property was for sale. It was realised that the appliances at hand were inadequate for the economic winning and treatment of the refractory ores occurring in the deeper levels, and that the mine could only be satisfactorily worked by a company with a considerable amount of capital.

In December, 1890, an area of 1,033 acres, including the Reform Mine, the New Reform Pups, and the other veins previously worked in small claims, was acquired by the Wentworth Gold-fields Proprietary Company, Limited, with a capital of £500,000, and in June, 1892, a subsidiary company, called the Aladdin's Lamp Gold-mining Co., with a capital of £100,000, was formed to work thirty-eight acres of the previously mentioned area.

There is no doubt that the Wentworth Gold-fields Proprietary Co. was largely over-capitalised, as only a comparatively small portion of their enormous area contained payable auriferous deposits; and in view of the isolated character of the rich auriferous deposits (the mode of occurrence of which will be presently described), and the expensive "dead work" which is a necessity during the operations of prospecting for new bonanzas, it was hopeless to expect that the mine could continue to pay interest upon such an enormous nominal capital.

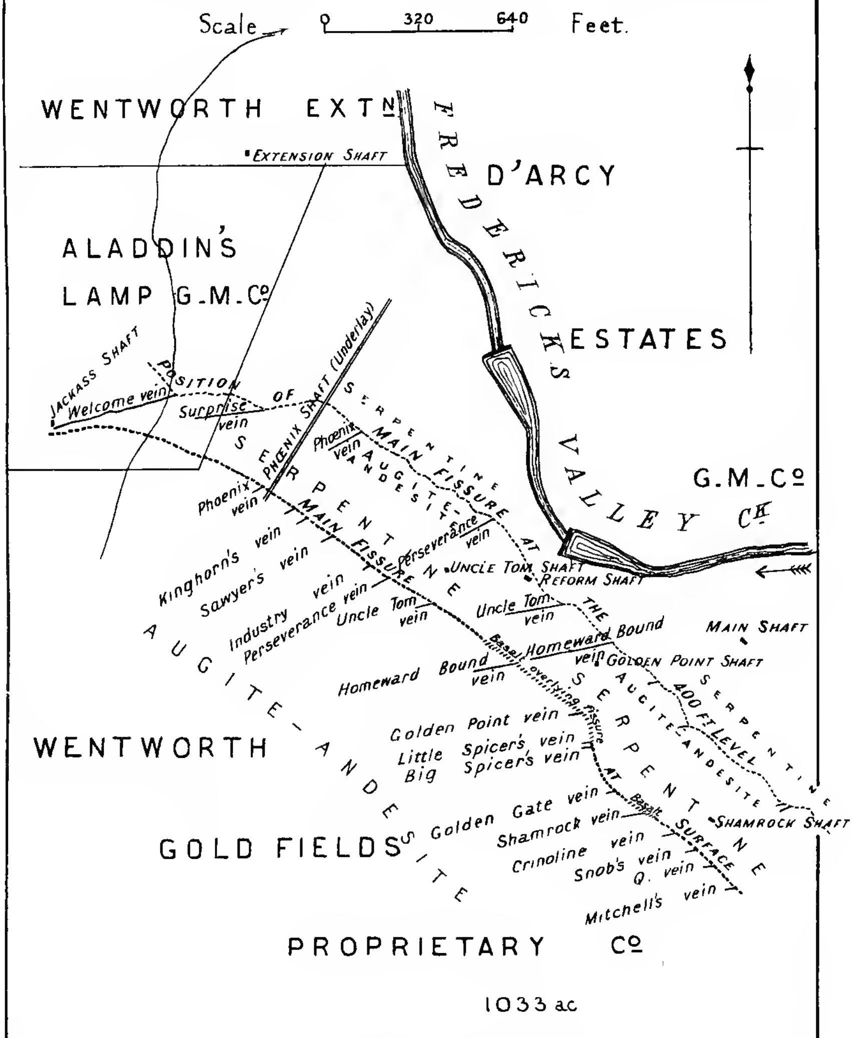
Vigorous prospecting was commenced after the formation of the company, resulting very shortly in the discovery of extremely rich deposits of gold, as the returns which are appended will show.

Return showing Ore won and Gold obtained from the Wentworth Gold-fields Proprietary, and Aladdin's Lamp Mines, from 1892 to 1899, inclusive.

| Year. | Wentworth Gold-fields Proprietary. | | | Alladin's Lamp Company. | | |
|---|---|---|---|---|---|---|
| | Tons of Ore. | Ounces of Gold. | Value. | Tons of Ore. | Ounces of Gold. | Value. |
| | | | £ | | | £ |
| 1892 | ......... | 8,264½ | 31,358 | ......... | 10,436 | 38,309 |
| 1893 | 10,000 | 8,992 | 35,262 | 2,500 | 5,636 | 21,966 |
| 1894 | 10,947 | 19,992 | 72,118 | 4,298 | 14,008 | 47,645 |
| 1895 | 9,381 | 58,100 | 203,350 | 3,889 | 23,078 | 80,773 |
| 1896 | 9,368 | 12,048 | 42,564 | 3,052 | 16,718 | 58,195 |
| 1897 | 6,225 | 5,281 | 18,752 | 3,027 | 6,064 | 20,710 |
| 1898 | 10,870 | 17,600 | 61,600 | 4,866 | 7,344 | 22,032 |
| 1899 | 6,434 | 3,956½ | 14,572 | 6,605 | 7,185½ | 26,603 |
| | 63,225 | 134,234 | 479,576 | 28,237 | 90,469½ | 316,233 |

*Description of the Deposits.*—The mode of occurrence of the rich deposits of auriferous ore in these mines is extremely interesting. They are found invariably under the same conditions, viz., as chutes, pipes, or bunches of ore at or near the junctions of a number of the east and west veins with a main fissure, whose general direction or strike is north-west and south-east. The main fissure is vertical in some places, and nearly horizontal in others, but it has a general dip to the north-east at an average angle of 60°. It is known locally as

# Sketch Plan of part of the LUCKNOW GOLD FIELD

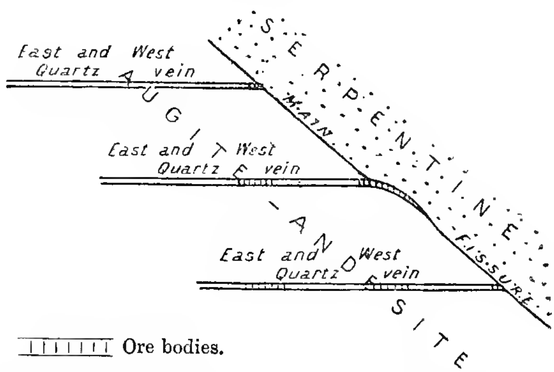



(Taken from Mining Managers' plan)

48466

*Photo-lithographed by W. A. Gullick, Government Printer, Sydney, N.S.W.*

"the lode" or "the joint," and some writers have asserted that it is neither a lode or a fissure. The term lode is doubtless somewhat misleading, inasmuch as the ore-bodies only occur at or near where the east and west veins junction with it, and elsewhere the walls are contiguous to one another, forming a mere plane of section. Nevertheless there is abundant evidence in the mine to show that it has been a genuine fissure, for numerous striated slickensides (in some cases a polished surface of stibnite) supply proof of movements of the hanging walls after the fracture had taken place, and distinct faults are also visible in it in places. No evidence, however, appears to exist of its having thrown, or been thrown by, the east and west veins.




SKETCH PLAN SHOWING MODE OF OCCURRENCE OF ORE BODIES IN THE LUCKNOW MINES.

The rock forming the north-eastern or hanging wall of the main fissure, in those places where the productive deposits occur, is a mottled dark-green and white serpentine, while the south-western or foot-wall is formed of a greenish-grey augite-andesite, locally termed diorite. Occasionally the augite crystals impart to this rock a porphyritic structure on a small scale. Where the andesite forms the hanging wall of the main fissure it often exhibits the effects of crushing.

It seems to be an invariable rule in this mine that deposits of auriferous ore only occur where serpentine forms the hanging wall of the main fissure; where both walls of the fissure are composed of andesite there is no ore-body. Occasionally rounded masses of hard rock, termed "boulders" by the miners, are found embedded in the serpentine of the hanging-wall; these are easily separated from the enclosing rock, and are of various sizes, from a few inches up to many feet in diameter. They have a skin or coating of serpentine on the outside, but on being broken they are seen to consist of the same rock as that forming the foot-wall of the fissure, viz., augite-andesite.

Some little distance to the north-east of the serpentine the latter is again succeeded by augite-andesite; in short, the serpentine forms a narrow lenticular belt, about 300 feet in its maximum width, bounded on its south-western side by the main fissure, which also separates it from the andesite.

This remarkably sharp boundary between the two formations, when considered in conjunction with the occurrence of the round masses ("boulders") of andesite embedded in the serpentine, naturally suggests the idea that the serpentine has been derived from the decomposition of the augite-andesite. A microscopic examination of thin slices of a number of specimens of rock, from both the hanging and foot walls of the fissure, has lately been made by Professor David, and fully bears out this assumption. In many cases the porphyritic crystals of augite show, under the microscope, every stage of passage from a condition of unaltered pyroxene into pseudomorphs of serpentine. Similar evidence was obtained from thin slices of the hard rock forming one of the round masses or "boulders." An apparently homogeneous rock of dark colour, which is termed "black rock" by the miners, and which is sometimes found between the typical serpentine and the andesite, is seen, under the microscope, to consist of dense serpentine. An extremely hard and tough rock of a light greenish-grey colour, which has received the name of "old man" from the miners, consists of nephrite or jade. This rock only occurs where there is an ore-body, and is then found, a foot or more in width, between the ore and the hanging wall of serpentine.

The east and west veins come in from the westward, and junction with the main fissure, but never, under any circumstances, continue across it. Altogether seventeen of these veins have been found, and they have been given distinctive names, such as the "Welcome," the "Homeward Bound," the "Surprise" the "Perseverance," etc. They are generally either vertical or inclined at a high angle, and they vary in width from a few inches up to six feet, or occasionally ten or fifteen feet. They have usually a more or less banded structure, and the filling is principally quartz (with included lenticular masses of augite-andesite) until they approach the main fissure, when the quartz gives place to calcite, which invariably carries the rich auriferous ore in the vicinity of serpentine. In the upper workings of the mine (above the 200 feet level) the quartz is said to have contained much gold in the free state, but in the lower levels the gold is never, under any circumstance, found in payable quantities in a quartz gangue, but invariably (both in the free state, and as auriferous mispickel) with calcite.

There is no known instance in the mine of an auriferous ore-body which was not connected with one of these east and west veins, and, as already stated, the ore is found either at or near the junction of the vein with the main fissure. In consequence of this fact very few of the east and west veins have been explored for any great distance from the junction, as the quartz only contains a very small proportion of gold (probably about two pennyweights per ton); but in one instance, viz., in the "Homeward Bound" vein, at the 400 feet level, three distinct chutes of calcite, containing rich ore, were found and extracted. One of these was, as usual, at the junction, while the other two were in the "Homeward Bound" (east and west) vein, separated by barren areas of quartz, the third chute being situated 240 feet from the main fissure.

Below the 600 feet level, what are termed "droppers" are of frequent occurrence in the vicinity of the main fissure. These are irregular offshoots from the rich ore-bodies, extending downwards, in the andesite, from the footwall. They vary in length from a few feet up to fifty or sixty feet. They are similar in composition to the rich ore-bodies to which they form extensions, consisting of auriferous mispickel in a calcite gangue, though sometimes the main ore bodies are found to be impoverished near where the "droppers" occur. In one instance (Surprise Vein) a second "dropper" was found as an offshoot from the first.

When the hanging wall of the main fissure, at its junction with an east and west vein, is not composed of serpentine, there is an absence of ore; and whenever calcite is found in the fissure, with andesite forming both walls, no ore occurs in it. In the unoxidised zone, therefore, auriferous deposits are only found in this remarkable mine under the following conditions, viz.:—

(1) At or near the junction of an east and west vein with the main fissure;
(2) When serpentine forms the hanging wall of the main fissure; and
(3) When the gangue consists of calcite.

Again, the ore-bodies occur in four ways, viz:—

(1) As chutes or pipes along the junction of the quartz veins with the main fissure, with a length of from forty to fifty feet;
(2) As bunches extending horizontally along the main fissure, but always starting from the toe of a quartz vein;
(3) As "droppers" from the foot wall of the main fissure;
(4) As chutes in the east and west veins (near their junction with the main fissure), where calcite replaces the quartz for some short distance.

*Character of the Ore.*—In the upper levels the gold was in the free state, associated with quartz, ferruginous sandy clay, and yellowish brown siliceous accretions, locally termed "clinkers"; but in the unoxidised zone it is contained principally in extremely rich arsenical pyrites (mispickel), with which metallic antimony is generally (and stibnite occasionally) associated. Iron pyrites is often present in small quantities, and in the lower levels pyrrhotine sometimes replaces the mispickel; in such cases there is a corresponding falling off in the gold contents. It is characteristic of the mispickel that it occurs in masses, from half an inch upwards in diameter, of beautiful stellate or radiating crystals. These starlike masses are known by the miners as "Prince of Wales Feathers." The mispickel is generally extremely rich in gold, the clean mineral containing at the rate of from fifty to 500 ounces per ton. Where free gold is associated with the arsenical pyrites, the values are, of course, much higher; thus, a specimen presented to the Geological Museum by Mr. C. G. Warnford Lock, the late Superintendent of the Mines, yielded by assay at the rate of 16,510 ounces of gold bullion per ton. (The gold is alloyed with some silver, and the bullion is worth about £3 10s. per ounce.)

*Extent of the Workings.*—The main fissure has been driven upon, at various levels, for a continuous length of 4,000 feet, which represents a considerable amount of expensive "dead work" between the successive east and west veins. As the andesite is a very hard and tough rock, though it requires little or no timbering, the mine has been an exceedingly expensive one to prospect, both by reason of the irregularity and capricious nature of the ore-deposits, and on account of the difficulty in following the main fissures, as parallel "false joints" are often mistaken for it. Some extremely rich shoots or "bonanzas" were met with at depths of from 500 to 700 feet. Thus, in the "Welcome" stopes, at the 500 feet level, the ore body was from seven to eight feet wide, half of it consisting of clean mispickel, with free gold, and the full width averaging about fifty ounces per ton. Over two tons of gold bullion were obtained here within a few weeks. In the "Welcome" vein, near its junction with the main fissure, at a depth of 700 feet, a fine body of ore was found, ten feet wide and fifty feet long, averaging about fifty ounces of gold per ton. Fifty feet below this the ore body pinched out completely (though the quartz vein continued), and there was no serpentine to be seen on the wall of the main fissure. Up to the present time no ore-bodies have been discovered below a depth of 780 feet. At the 800 feet level the junction of the "Surprise" vein has been found where there is no serpentine, and no ore. Similar conditions occur at the junction of the "Welcome" vein at the same level. The greatest depth yet attained in the mine is 1,000 feet, where the only vein hitherto struck is supposed to be the "Homeward Bound," and this has thinned out and split into four small strings, which do not reach the fissure by fifty or sixty feet. They do not contain any ore, nor is there any serpentine on the hanging wall of what is supposed to be the main fissure at this level. Owing to the apparent absence of ore, or of the conditions which usually accompany ore, in the deeper levels, it is understood that the officials of the mine are inclined to take a gloomy view of its future prospects. It must be borne in mind, however, that this property has been justly termed a mine of surprises, and it is reasonable to expect that other rich deposits will be found at much greater depths than have hitherto been attained. There is no certainty that the true main fissure has been found at the 1,000 feet level, and there is plenty of room to have missed it in the unprospected ground. The adjoining land on the north-east is held by the Darcy Estates Gold-mining Company, who have sunk a vertical shaft to a depth of 1,000 feet, without meeting with any considerable body of ore. Mining operations have been stopped for a considerable time, but it is understood that fresh capital has now been provided, aud prospecting is about to be continued. Should any success be met with in the deep ground it would give encouragement to the Directors of the Wentworth Mine to continue to develop their property.

*Depths of Principal Shafts.*

The Jackass Shaft.—This is a vertical shaft, 591 feet deep, or, including the sump, 605 feet.

The Phœnix Shaft, inclined at an angle of $40\frac{1}{3}°$, has a depth of 1,100 feet, which is equal to 712 feet vertical.

The Reform Shaft is vertical for 394 feet, below which an inclined winze extends at an angle of $66\frac{1}{2}°$ for a distance of 216 feet, reaching a total vertical depth of 592 feet.

The Main Shaft is vertical, and is 810 feet in depth. An inclined winze from the 800 feet level extends to a depth of 1,000 feet (vertical) from the surface.

*Genesis of the Ore Deposits.*—It is impossible to speak with any certainty as to the exact mode of origin of these extremely interesting deposits, but the conditions under which they occur are so constant that their significance cannot be overlooked in any attempt to trace the gold to its source. With regard to the formation of the ore bodies along the main fissure, the evidence obtained from the deep workings, so far as it goes, appears to favour Sandberger's theory of lateral secretion. There is no difficulty in accounting for the presence of sulphides and arsenides in the ore-bodies, as small crystals of pyrites and mispickel are disseminated through the augite-andesite, and in the same way the calcite forming the gangue may be presumed to have been derived from the decomposition of the crystals of the augite and other lime-bearing minerals in the same rock. From the fact that the auriferous ore is always found either in contact with the serpentine, or but a short distance from it, and connected with it by fissure veins, there seems to be strong reason for directly connecting this rock with the origin of the gold deposits. It seems probable that the history of the deposits is as follows:—The decomposition of a belt of augite-andesite, with the consequent formation of serpentine, took place before the formation of the fissures, though the exact cause of the decomposition of this particular belt is not clear. Subsequently, owing to earth movements, fissuring took place, the main fracture following the line of least resistance, viz., the boundary between the serpentine and the solid andesite, while the cross open fissures occurred at intervals on the south-western side of this line, the direction of all of them being approximately parallel. Ascending hydro-thermal solutions having attained access to these cross fissures, they gradually became filled with depositions of quartz, alternating with lenticular masses of andesite which fell from the walls, thus imparting to the veins their banded appearance. But during this gradual process the hydro-thermal solutious also percolated through the joints of the serpentine, dissolving lime from the decomposed augites, probably taking the gold from the same source, and sulphides and arsenides from the minute crystals of pyrites scattered through the rock. Finally these solutions found their way laterally to the only existing cavities, viz., where the east and west open fissures junctioned with the main fissure, and there, under normal conditions of atmospheric pressure, they deposited the ore-bodies, consisting of auriferous mispickel in a gangue of calcite.

*Local Treatment of the Ore.*—The only treatment to which the ore is subjected at the mine consists of reduction and concentration, the products being classed as "firsts," "seconds," and "tailings." The battery, which is furnished with rockbreakers and automatic feeders, contains thirty-five stamps, weighing 850 pounds each; they have a drop of six and a-half inches, and with a speed of ninety-six strokes per minute. The stamp duty is one and three-quarter ton per twenty-four hours. The depth of discharge is four inches, and the gratings are of 900 mesh. This battery deals with the ore from both the Wentworth Gold-fields Proprietary and the Aladdin Mines. What are termed "firsts," are obtained from hand-picked and very rich ore. This is put through a five-head battery, and the free gold is saved on the amalgamated copper plates and in the stamper box. The remaining portion of the crushed material (constituting "firsts") is run off the tables into a tank and sold to the Dapto Smelting Works on assay. It yields from thirty to 500 ounces of gold bullion per ton. The "seconds" are obtained by concentration from the ore forming the bulk of the deposits after the richer portions, or "firsts," have been removed by hand picking. This ore is crushed in the battery, and, here again, the free gold is retained in the boxes and on the plates; the pulp then passes on to Frue vanners, of which there are fourteen in the mill. The concentrates from the vanners ("seconds"), contain from five to seventy ounces of gold bullion per ton; they also are sold to the Dapto Smelting Works on the basis of their assay value. The tailings and slimes are collected in a heap, which, at present, is estimated to contain about 60,000 tons, carrying from five to eight pennyweights of gold per ton. It is intended to treat these tailings by the cyanide process, but the treatment has not been successfully demonstrated as yet, owing to the difficulty of getting the slimes to settle in the vats. It is probable, however, that this will be overcome by the use of filter presses, or by subjecting the tailings to a slight preliminary roast.

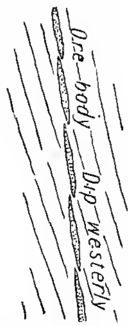
### 3. Impregnations of Gold in Slate, Quartzite, Volcanic Tuff, etc.

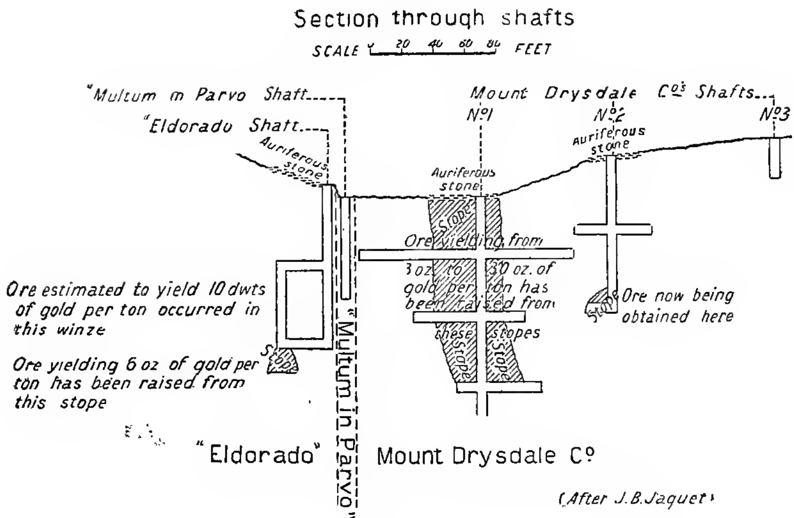
*Gold in Slate.*—In several widely-separated parts of the Colony gold has been found in slate rocks. At Mount Allen, twelve miles from Mount Hope, a bunch of iron ore was worked as a flux for the Mount Hope Copper-mining Company's ore. This iron ore proved to be auriferous, and a shaft, fifty feet deep, was sunk at a distance of about twenty feet from the edge of the iron ore deposit. The shaft was entirely in red fissile slate, and very fine plates or flakes of gold were freely visible between the laminæ of the slates. A bulk sample of two tons of the slate was treated in Sydney, and was said to have yielded at the rate of two ounces of gold per ton. Drives were put in from the bottom of the shaft to the four points of the compass, but the gold was not found to be payable for any distance, and it is probable that it owed its origin to the auriferous solutions which enriched the iron ore, and which had percolated for about twenty feet through the slates which bounded the latter. Samples illustrating this occurrence may be seen in the Geological Museum. Another somewhat similar instance occurs about eight miles north of Grong-Grong, in the Narrandera district. A reef called the Belmore was opened about thirty-five years ago, and proved extremely rich in gold near the surface. It was about four feet wide, and its strike was north-west. The eastern wall is composed of blue, green, and purple slates, and the western of quartz-grits and sandstones. Fine scales of gold are visible between the laminæ of the slates, but the enrichment does not extend for any distance from the reef, and the origin of the precious metal is probably to be accounted for in the same way as in the instance previously mentioned. The occurrence of gold in slate in the Cobar district is of much more importance. Fine gold was observed in slate in the cap of the Great Cobar copper lode, but the first instance in which payable gold was obtained in these sedimentary rocks was in the mine known as the Cobar Chesney.

It has since been found in the Fort Bourke Mine, the Young Australia, the Mount Pleasant, the Great Western, the Occidental, and the Peaks. In the Great Western the gold is associated with native copper, and returns of as much as five ounces per ton, and three per cent. of copper have been obtained. In the Occidental an average yield of three pennyweights of gold per ton was obtained in ferruginous slate, and the deposit was worked by an open cut to a depth of 100 feet. The Peaks was formerly known as Barrass and Conley's Mine, but it now belongs to the Great Cobar Company. Here the gold occurred in patches in slates (which were ferruginous in places), quartzites, and bunches of ironstone, and some very rich returns were obtained. Rich deposits of chloride of silver were also met with in these rocks. The Peaks Mine was worked by open cut and also by shafts. Bedded deposits of quartz and quartzite are of frequent occurrence in most of these mines, but they are not, as a rule, found to contain gold.

Still more remarkable were the deposits of gold in sedimentary rocks a few years ago at Mount Drysdale, about twenty-five miles

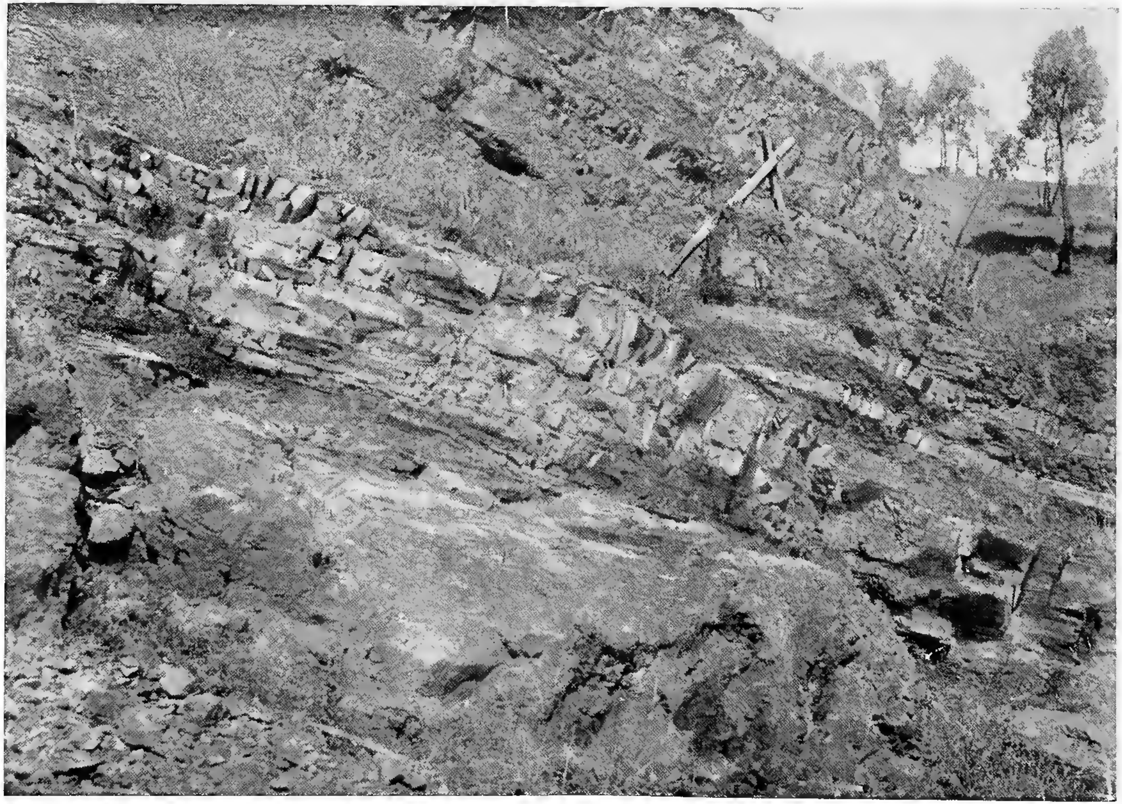
Ideal Section showing apparent breaks in the Drysdale ore body.




Sections, Mount Drysdale.

north of Cobar. In the year 1892 alluvial gold was found on the plains to the west of Mount Drysdale, and about 300 ounces, valued at £2 15s. per ounce, were obtained. This led the miners to search



*Photographed by E. F. Pittman.*

CHARACTER OF THE ORE-BODIES AND INTERCALATED CLAYSTONES, LYNDHURST GOLD-FIELD.

for the source of the precious metal, and the result was the discovery of the Mount Drysdale and Eldorado Mines. The gold occurs in these mines in more or less altered slates, sandstones, conglomerates, and breccias, which are probably of Silurian age. There are numerous quartz reefs in tho rocks, but they do not extend for any distance, either vertically or horizontally, and they are not gold-bearing. The gold is visible to the naked eye in some places in the sedimentary rocks, but more frequently it occurs in very minute and invisible grains, and there is no apparent difference between the richest and the most barren rock. The rich ore occurred in a pipe-like chute, which was about forty feet long, and which varied in width from six inches near the surface, to about five feet at the 125 feet level. Chloride of silver was associated with the gold in varying proportions. During the twelve months ending November, 1894, about 2,300 tons of ore, which yielded from six to thirty ounces of gold per ton, were won from the Mount Drysdale Mine, and dividends amounting to £22,784 were paid to the shareholders.

The above information is taken from a report on Mount Drysdale by Mr. J. B. Jaquet, Geological Surveyor.

Quite recently rich ore has again been met with in the Mount Drysdale Mine, and some good returns are now being obtained.

*Gold in Schists.*—Talc schists, mica schists, and chlorite schists are found to be auriferous in places, as at Guudagai, Caloola Creek, Albury, the Orange district, &c.

*The Auriferous Ore-beds of the Lyndhurst Goldfield.*—Some of the most remarkable auriferous deposits in New South Wales are situated on the Belubula River, in the parishes of Lyndhurst and Belubula, county of Bathurst, about eight miles West by South from the town of Carcoar.

The geological formation here consists of a series of banded sedimentary rocks, consisting of indurated bluish-grey claystones, alternating with intercalated ore bodies composed of a highly altered rock containing bunches and impregnations of auriferous mispickel, pyrrhotine, and iron pyrites. This sedimentary series has been intruded by hornblendic granite, and also by dykes and sills of diorite, apparently off-shoots from the granite massif. There is also another series of dykes consisting of augite-andesite.

The deposits bear a most striking resemblance, in their general appearance and mode of occurence, to the banded claystones and tuffs of the Tamworth Common (distant over 200 miles to the north-east), and the analogy is further emphasised by the occurence, at both localities, of radiolaria in the claystones, and by the presence, in the Lyndhurst ore-bodies, of occasional small lenticular masses of dark bluish-grey limestone, identical in appearance and character with the masses of limestone which form so typical a feature of the Tamworth tuffaceous beds. Radiolaria are very plentiful in the limestones at

Tamworth (where they were first recognised by Professor David), and they also occur in those at Lyndhurst, although not in such a perfect state of preservation as at Tamworth.

The Tamworth tuffs and claystones, however, are associated with massive beds of limestone containing corals identical with those occurring in the Burdekin beds of Queensland, and they are, therefore, considered to be of Devonian age; the Lyndhurst claystones, on the other hand, contain fossils which indicate that these deposits are certainly not newer than Lower Silurian. Associated with the radiolaria the Author has found Trilobites (apparently *Agnostus*), bivalve shells (probably *Obolella*), and Graptolites (*Diplograptus*, and *Climacograptus*). The graptolites are very numerous in a dark bluish-grey shale. Several specimens were forwarded to Mr. T. S. Hall, of the Melbourne University, who has described two of them as new species.*

It is also interesting to notice that distinct *Girvanella* structure was recently recognised by Mr. G. W. Card, A.R.S.M., while making a microscopic examination of a thin slice of one of the ore-bodies.

The claystone beds and ore-bodies at Lyndhurst vary in thickness from that of a sheet of paper up to twenty feet. In places the recurrence of extremly thin beds, differing in material and colour, has resulted in the formation of a banded rock of remarkable regularity, and which cannot be distinguished from the banded rocks (tuffs and claystones) of Tamworth.

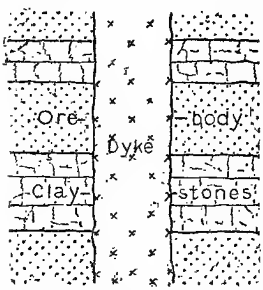
The dip of the Lyndhurst beds is variable and undulating, and the surface configuration of the hills, due to atmospheric denudation, accords, in a majority of cases, with the inclination of the bedding planes of the strata. The lines of junction between the ore-bodies and the claystones present features which appear to point to the conclusion that the former have intruded the latter. This is particularly noticeable in the very thin beds of the banded rocks, where the bands of claystone have frequently been broken, faulted, and apparently, in some cases, partly absorbed by the ore-bodies. Precisely similar phenomena are common in the Tamworth series, where the tuffs present all the appearances of having intruded the claystones while the latter were still in a plastic condition. Within a depth of from twenty to forty feet from the surface, the ore-bodies at Lyndhurst have been very much decomposed, and now consist of a friable gossanous material containing free gold, while the claystones have weathered to a pale yellowish-white colour, and in some cases have the appearance of thin beds of kaolin.

These ore-bodies were worked for gold quite twenty years ago in three mines situated within half a mile of another, and known as "The Junction Reefs," "The Frenchman's," and "The Cornishman's," respectively. Some very rich deposits of gold were obtained from the former, and were doubtless derived from the decomposition of the

* Records Geol. Survey N.S. Wales, 1900, VII, pp. 16, 17.

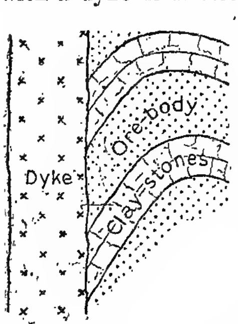
auriferous sulphides. Mining operations were, however, confined to the oxidised portions of the deposits during the earlier periods of the mines' history, no attempt being made to treat the undecomposed ore-bodies. The rich gold only occurred in patches, while the bulk of the gossan was of low grade; and as it was not considered probable that the pyritous ore would pay for the extraction, the excavations were not carried to auy great depth. In all three mines the productive ore-bodies were intersected by dykes of diorite and augite-andesite, aud there are good reasons, therefore, for concluding that the enrichment of the ore-bodies was due to the influence of these intrusive rocks.

The structure of the ore-bodies has been so much changed, apparently by the influence of hydro-thermal solutions, that it is a matter of great difficulty to determine what their original components were.




Their interstitial spaces and joints have been filled by secondary silica and calcite; and as already stated, they have been largely impregnated with auriferous sulphides, such as mispickle, pyrrhotine, and iron pyrites.

The evidence of intrusion which is supplied by the junction with the claystones, both on their upper and lower surfaces, would, at first-sight, suggest that they had originally been formed as sills or intrusive sheets, which, as offshoots from the diorite or andesite dykes, had been thrust in between the bedding planes of the claystones. On the other hand, this supposition is upset by the manner in which the ore-bodies are found to junction with the dykes. Wherever one of them is seen in contact with a dyke it is noticeable that the two are not continuous at the junction, but there is a distinct wall or plane of division between them, and there is a striking difference in the appearance and composition of the rocks; in short, the evidence is in favour of the dykes being of more recent age than the ore-bodies. Occasionally the ore-bodies and claystones are seen to bend downwards at their junction with the dykes, as is so often the case where sedimentary rocks are intruded from below by igneous dykes. Moreover, although there are some undoubted sills at Lyndhurst, they are distinct, in their mode of occurrence as well as in their composition, from the ore-bodies. In the bed of the Belubula River, opposite the old "Cornishman's" Mine, a number of fine examples of intrusive sills occur. They branch off from the main diorite dyke, which trends across the field in a N.N.W. and S.S.E. direction, and they are distinctly hornblendic in character, numerous

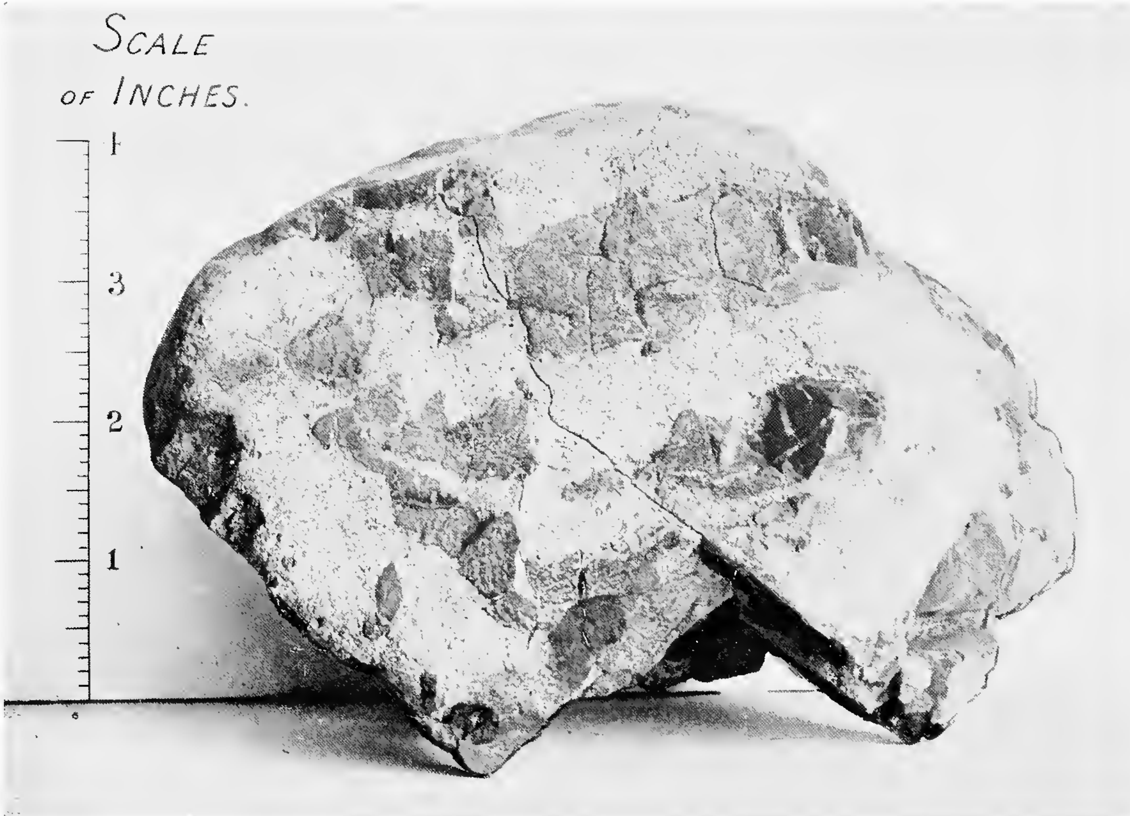


crystals of hornblende being visible in them to the naked eye. They have an uninterrupted junction with the parent dyke, and they vary in thickness from a few inches up to as much as fifty feet. Even the smallest sills, however, have produced most remarkable contact metamorphism of the overlying and underlying strata. An extremely hard, white, cherty rock has resulted from its influence, crystals of garnet have been formed, and at the actual line of contact the rock has been fused, so that the diorite and chert appear to pass insensibly into one another.

Now, in the case of the ore-bodies, although they appear as if they had intruded the claystones, and the actual line of contact is irregular, there is no gradual passage of the one rock into the other, the material of the two being always distinct; moreover, although the claystones are much indurated, they show no evidence of actual contact metamorphisms similar to that described above, and which might have been expected if the ore-bodies had originally been intrusive sills; for it must be borne in mind that some of the ore-bodies are as much as twenty feet in thickness, and they have been proved to extend for a horizontal distance of at least half a mile.

*Probable Origin of the Lyndhurst Ore-Bodies.*—In view of the remarkable analogy which exists between these deposits and the banded rocks of the Tamworth section, there seem to be strong reasons for the assumption that they have had a similar origin. The Tamworth series, as already stated, consists of alternate beds of tuff and claystone. There are in the Lyndhurst series undoubted beds of tuff also, some of them resembling a very coarse conglomerate and containing pebbles or rounded masses of claystone several inches in diameter, while in others again the included fragments of claystone are exceedingly angular, and appear to be the remains of beds of claystone which have been intruded and broken up by the tuffaceous matrix through which they are now scattered.

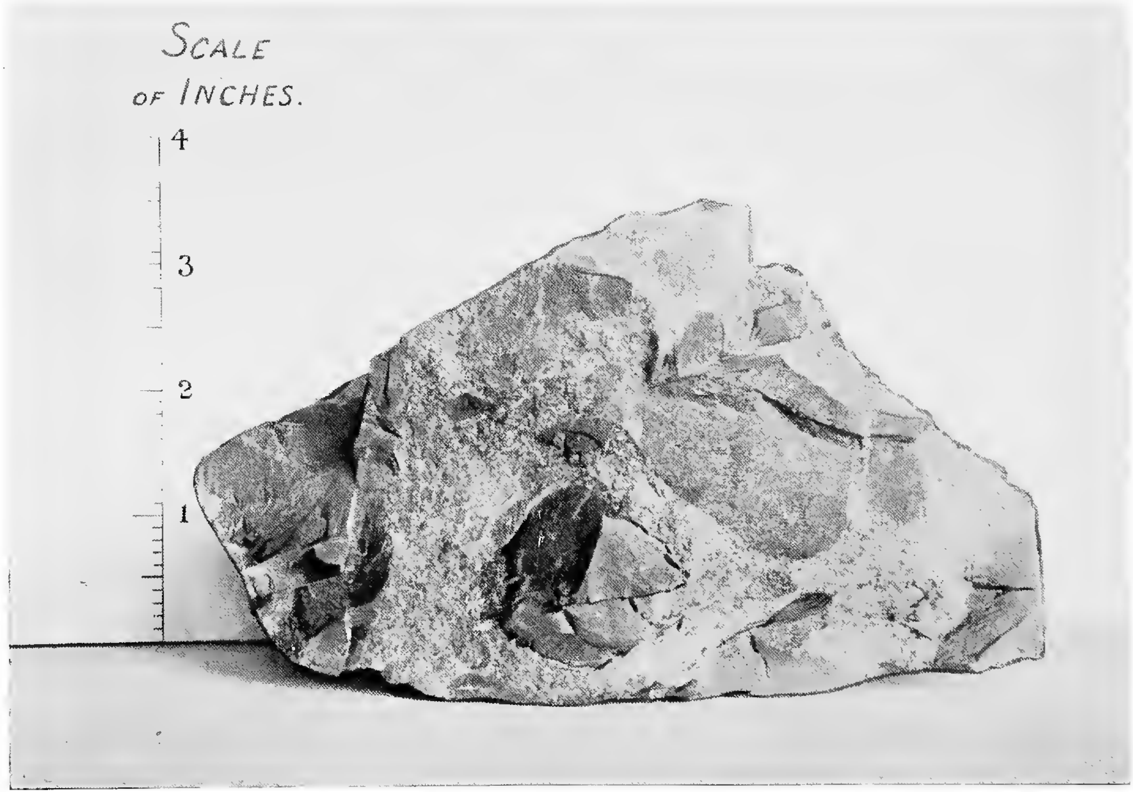
Taking all the evidence into consideration, it would appear as if the ore-bodies at Lyndhurst had also, originally, been porous submarine tuffs, which were laid down contemporaneously with beds of mud (now forming claystones) during intermittent periods of intense volcanic activity; that while these tuffs and claystones were still in a more or less plastic condition they were subjected to much disturbance from the injection of steam and other gases, which caused the intercalated beds of tuff to intrude, break up, and, in places, envelop isolated portions of the claystone. Subsequently there was an intrusion of hornblendic granite, while offshoots therefrom, in the shape of dykes and sills of diorite and augite-andesite, intersected the sedimentary series in all directions. These intrusions produced induration of the claystones, while the more porous tuffs were permeated by hydrothermal solutions, which had the effect of almost entirely obliterating their original structure, while filling their interstices and joints with depositions of calcite and secondary silica, and with bunches and impregnations of auriferous sulphides and arsenides.




*Photographed by E. F. Pittman.*

EXAMPLE OF INTRUSIVE TUFF FROM LYNDHURST GOLD-FIELD.

(The dark angular fragments are composed of indurated claystone; the lighter portions consist of volcanic tuff containing felspars and lapilli of various volcanic rocks.)

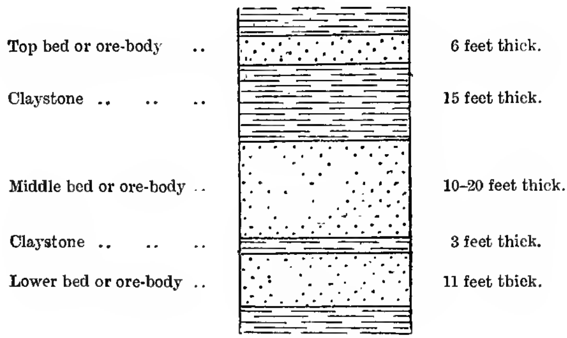



*Photographed by E. F. Pittman.*

EXAMPLE OF COARSE VOLCANIC TUFF FROM LYNDHURST GOLD-FIELD.

(The dark rounded fragments are composed of indurated claystone; the lighter matrix consists of tuffaceous material containing felspars and lapilli of various volcanic rocks.)

*Extent of the Auriferous Deposits.*—At the present time, about 500 acres of these deposits, including the three old mines ("Junction," "Cornishman's," and "Frenchman's") are held by a company known as the Lyndhurst Gold-field, Limited. Only three beds or ore-bodies have as yet been prospected by the company, and these are represented in the following section, though their thickness varies to a considerable extent in different parts of the field:—




Although all three bodies were extensively worked in the old "Junction," "Cornishman's," and "Frenchman's" Mines, where they occurred in a very decomposed state, and where the gold, in consequence of its having been set free from the sulphides, was easy of extraction, in the newer workings of the company, where the ore is in an undecomposed condition, attention has been devoted principally to the middle ore-body. A number of drives and crosscuts has been excavated in the lower six feet of this bed (the upper portion being said to be poorer) chiefly with the object of opening up and systematically prospecting the deposit; and, according to the statement of the underground manager, the ore has been found to vary in assay value from three pennyweights to over two ounces of gold per ton. Very little prospecting has been done in the other beds, but what evidence is available appears to show that the ore contained in them is of nearly equal value.

It seems probable that this enrichment of the ore-bodies is due to the intrusion of the igneous dykes and sills (for all the payable deposits hitherto worked have been in the immediate neighbourhood of these intrusions); and if this supposition be correct, it is reasonable to expect that the beds will become impoverished as they are followed to a distance from the intrusive rocks. All the workings have hitherto been confined to three comparatively restricted areas, for the excavations made by the present company are situated close to the old

"Cornishman's" Mine; and although igneous dykes have been found intersecting all the ground recently opened up, it is not known to what distance they extend, and the prospecting operations of the Lyndhurst Gold-field, Limited, will therefore be awaited with interest. In the meanwhile, however, it may be stated that fairly large ore reserves have been developed.

*The Reduction Plant.*—The Company possess a magnificent dam in the Belubula River, providing a practically unlimited supply of water-power for reduction and concentration purposes. The retaining wall is of concrete, backed by six massive arches of brickwork. The dam is situated at an altitude of about 200 feet above the crushing mill. The water, which is conducted to the mill in fifteen-inch steel pipes, is used to drive Pelton wheels, by which all the machinery (including battery, air-compressing plant for rock-drills, and electric lighting plant) is actuated. The one pipe-line provides about 300 horse-power. The battery is fitted with rock-breakers and automatic feeders. There are thirty-five stamps of 800 pounds each, which are driven at the rate of eighty-five blows per minute. The depth of discharge is one inch, with new dies, and screens of 140 holes to the square inch have been employed. A stamp duty of two tons per twenty-four hours has been obtained. It may be said, however, that hitherto the work performed at the mill has been rather of an experimental nature, and the best method of treating the ore has perhaps not yet been decided upon. The plant is also provided with ten Lührig and four Woodbury vanners, and the latter have been found most suitable for the class of ore which has to be treated here. There are four Pelton wheels, the three largest having diameters of six, four, and three feet respectively, while the fourth is a small Pelton motor for generating the electric light. It was at first attempted to treat the roasted concentrates by the chlorination process; but this proved a failure, owing to the large amount of lime contained in the ore. At the present time the concentrates from the vanners are carted to Burnt Yards, four miles distant, where the Company's experimental cyanide plant is situated. Very cheap and efficient roasting is here performed in an Edwards' furnace with a capacity of about fifty-five tons of raw concentrates per week. This furnace is fifty-five feet long and eight feet wide, and is encased by iron plates. The concentrates are fed into the upper end by an automatic feeder, and are worked forwards, along the slightly sloping bottom, by fourteen series of rabbles, which revolve on vertical axes protected by water-jackets. The roasted ore is pushed out of a hole in the bottom by the last rabbles, and is conveyed by a traveller to the cyanide vats. The roasted concentrates appear to be very suitable for treatment by the cyanide process, and some very good percentage extractions of gold have been obtained. It appears, however, as a result of the experimental operations hitherto carried out at the mill that there is little or no free gold in the undecomposed ore. There is, therefore, nothing to be gained by passing the pulp over amalgamated

*Photographed by E. F. Pittman.*

DAM ON THE BELUBULA RIVER. THE PROPERTY OF THE LYNDHURST GOLD-FIELD, LIMITED.

copper plates, or, possibly, even over vanners; and it is probable that the most satisfactory method of treatment will yet be found to consist of dry crushing, roasting, and cyaniding. The expense saved by omitting the intermediate processes of amalgamation and concentration would be considerable, and there is no apparent reason why the cyanide treatment should not be as effective upon the ore as upon the concentrates. For the sake of economy this treatment would, of course, be all carried out at the mill, in proximity to the mine.

*Quality of the Ore.*—The following battery returns represent the work done during the latter half of the year 1899, and will serve to give an approximate idea of the quality of the ore in the present workings:—

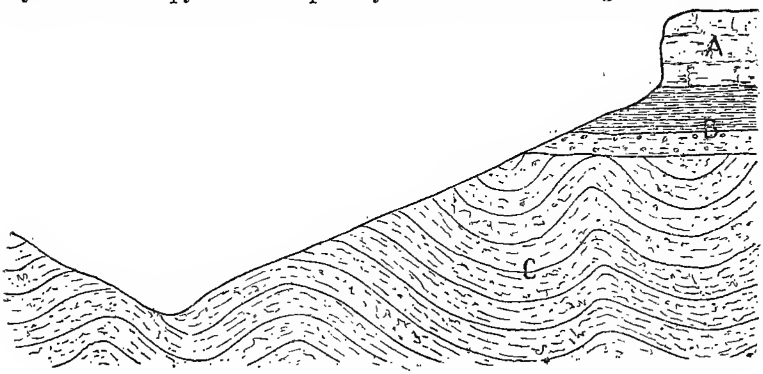
| Period. | Ore Crushed. | | Concentrates Obtained. | | Vanner Tailings. |
|---|---|---|---|---|---|
| | Tons. | Average Assay Value (Gold) per ton. | Tons. | Average Assay Value (Gold) per ton. | Average Assay Value (Gold) per ton. |
| 1899. | | oz. dwt. grs. | | oz. dwt. grs. | oz. dwt. grs. |
| July ... ... | 638 | 0 15 18 | 180 | 1 19 13 | 0 7 7 |
| August ... | 660 | 0 16 11 | 249 | 1 12 0 | ........... |
| September ... | 927 | 0 17 5 | 98 | 2 3 23 | ........... |
| October ... | 845 | 0 13 6 | 90 | 2 0 14 | ........... |
| November ... | ... | 0 7 19 | ... | 1 4 0 | 0 4 0 |
| December ... | ... | 0 13 12 | ... | 1 5 0 | 0 7 0 |

The average assay value of all the ore crushed during the six months was fourteen pennyweights of fine gold per ton.

*The Yalwal Gold-field.*—The auriferous deposits of Yalwal form another example of impregnations in stratified rocks. Yalwal is situated about eighteen miles west of the town of Nowra, on the Shoalhaven River. The rocks in which the auriferous deposits occur consist of indurated siliceous slates, quartzites, and conglomerates, which are probably of Devonian age. These are overlaid, unconformably, by the Upper Marine beds of the Permo-Carboniferous system, the highest strata of which (the Nowra Grits) form vertical escarpments.

The Valley of Danjera Creek, a tributury of the Shoalhaven, in which the township of Yalwal is situated, has been eroded through the Permo-Carboniferous Marine beds, and has exposed a narrow area of contorted and much silicified Devonian (?) sediments in which the gold is now worked.

There are no continuous reefs or lodes in the auriferous formation, but irregular minute veinlets of quartz, a few feet in maximum length, are occasionally seen traversing the quartzites and silicified slates. On the margins of these veins rich deposits or seams of gold are found, while all the rocks, including the conglomerates, contain a small proportion (one or two pennyweights per ton) of gold in grains, which, however, are not visible to the naked eye. Minute crystals of iron pyrites are sparsely disseminated through the stone.




A Nowra Grits .. .. .. .. .. .. } Permo-Carboniferous
B Shales and Conglomerates .. .. .. .. } (Upper Marine).

C Quartzites, Conglomerates, and Silicified Slates, containing gold .. .. .. } Devonian.

SKETCH SECTION OF THE YALWAL GOLD-FIELD.

The Pinnacle Mine was first opened in the year 1873, when some exceedingly rich stone was found on the surface, and yielded as much as twenty-three and a half ounces of gold per ton by hand crushing. Several thousands of tons of stone were afterwards taken out of this mine in open cuttings and irregular underground excavations. Some of it was very rich, more especially that from near the surface; much of it, on the other hand yielded only four pennyweights of gold per ton. This mine has been idle for some years.

In the Eclipse Mine, which adjoins the Pinnacle, a considerable amount of irregular work was done in endeavouring to follow the payable *chutes* of gold, and the average yield from the stone, exclusive of the rich patches, was about ten pennyweights per ton.

In the Caledonia Mine, on the opposite or eastern side of the creek, some extremely rich patches of gold have been obtained; thus, in the year 1895, a crushing of twenty-seven and a quarter tons yielded, in the local battery, 1,487 ounces; and from another parcel of one ton and three quarters, no less than 750 ounces of gold were extracted The tailings from the first-mentioned crushing were treated at the Clyde Metallurgical Works, and yielded at the rate of thirty ounces per ton, whilst seventy ounces of gold were obtained from the residue of the small parcel. The gold was worth £3 5s. per ounce. The

*Photographed by E. F. Pittman.*

Open Cut at the Homeward Bound Mine Yalwal.

*Photographed by E. F. Pittman.*

THE PIONEER AND HOMEWARD BOUND CRUSHING PLANTS YALWAL.

Company afterwards extracted about £10,000 worth of gold from the same working; but nothing like systematic prospecting has been done in this mine, and it has been idle for some time.

The Pioneer and the Homeward Bound are the only mines now working, and in both cases the ore is extracted from open cuts or quarries, which have now attained large dimensions. The quarries are situated on the top of a spur, at a considerable elevation above Danjera Creek. A tunnel has been driven in from the side of the spur to a point below the bottom of the quary, and connection has been established between the quary and the tunnel by means of a pass. Tho auriferous stone, as it is broken down, is thrown through this pass into the tunnel; a self-acting incline then conveys it from the mouth of the tunnel to the crushing mill, which is situated on the creek, some distance below.

The Homeward Bound battery consists of fifty head of stamps, forty of which weigh 770 pounds each, while the remaining ten are of 630 pounds weight. They are driven at a speed of sixty strokes per minute, with a drop of seven and a half inches, and with screens of 180 holes per square inch, and a stamp duty of one ton six and two-thirds hundredweights per twenty-four hours is obtained.

In the Pioneer battery there are forty stamps of 850 pounds weight, which are worked with a nine-inch drop, and a speed of seventy blows per minute. The screens are 180 mesh, and a stamp duty of one ton eighteen hundredweight is obtained.

The bulk of the ore now being treated in the Homeward Bound and Pioneer Mines is of a distinctly low grade—so low, in fact, that one wonders how a margin of profit can be made from it; but the occasional occurrence of rich patches, yielding at the rate of eight or ten ounces per ton, makes a welcome addition to the returns.

Very complete cyanide plants have lately been erected, and are doing good work on the tailings. The total cost of mining, milling, and cyaniding is under eight shillings per ton, and is probably lower than in any other mine in New South Wales. The massive nature of the deposits, enabling the ore to be extracted in open cuts, is of course a great factor in keeping down cost. At the same time, the milling and cyaniding appear to be both efficiently and economically performed.

The Yalwal deposits strike one as being specially adapted for treatment on a large scale, as is done, for example, in the analogous ores of the Treadwell Mine, in Alaska. If the Homeward Bound, and Pioneer Mines can pay their way (as they are understood to have done for some considerable time, in addition to materially reducing their liabilities) with only fifty and forty head of stamps respectively, it is evident that with batteries of 200 or 300 head they could be made to yield handsome dividends.

The Homeward Bound has already crushed about 40,000 tons of stone, and there appears to be no lack of similar ore on the field.

### 4. Impregnations in Igneous Rocks.

*Gold in Granite.*—Gold occurs in granite in many parts of the Colony, as at Timbarra, Barney Downs, Uralla (Rocky River), Young, Major's Creek, Araluen, O'Connell, and Wolumla; but in every instance noted, where the granite is auriferous, one of its constituents is *hornblende.* At Timbarra the granite is coarsely porphyritic, and is intersected by small quartz veins, some of which contain gold and some tinstone. The principal source of the gold, however, is iron pyrites, which occurs either as minute crystals disseminated through the granite, or as hunches up to a foot in diameter. The most productive portions of the granite are those where it is soft, or decomposed, and where it has been stained yellow and red by peroxide of iron, resulting from the decomposition of the pyrites. Two crushings of this material from Timbarra yielded, some years ago, at the rate of nine pennyweights of gold per ton. The granite is only pyritous in places, and therefore the payable gold is irregular in its occurrence. Detrital gold has, however, been worked with profit in nearly all the alluvial deposits draining from the Timbarra Hills. At Surface Hill, Poverty Point, about an acre and a half of decomposed granite was excavated and ground-sluiced, down to a depth of thirty feet in places, and the undecomposed granite below yielded from two to five pennyweights of gold per ton in a battery. On a branch of McLean's Creek, in this district, over 1,000 tons of soft ferruginous granite was crushed for a yield of seven pennyweights of gold per ton. It would appear, however, that the gold is not confined to the pyrites and small quartz veins, for on Barney Downs run, near Tenterfield, fragments of gold as large as a pea have been seen imbedded in the solid granite, without any indication that pyrites had ever been associated with it. At the Rocky River, near Uralla, very rich deposits of detrital gold were found in the alluvials formed from the denudation of hernblendic granite. Pyrites occurs disseminated through this rock also, and there is every reason to believe that the gold was set free by the decomposition of that mineral.

In the district of Young, or Lambing Flat, as it was originally called, there were 20,000 persons, in the year 1861, engaged at alluvial mining. The gold in these alluvial deposits was fine and scaly, for the most part, and this was, without doubt, derived from the surrounding hornblendic granite. Some specimens of coarser gold were found, however, with small pieces of quartz attached to them, indicating a quartz reef origin. One reef, intersecting the granite (the Garibaldi Reef), was worked with profit down to the water level.

At Major's Creek and Araluen, hornblendic granite and dykes of diorite occur. The alluvial deposits were very rich in fine scaly gold. Some of the gold undoubtedly came from quartz reefs, but the greater part of it was probably derived from the granite, or from the auriferous pyrites with which the granite is impregnated.

Specimens of auriferous granite from Major's Creek, Wolumla, and Timbarra can be seen in the Geological Museum. In the specimens from the two last named localities visible specks of gold occur.

Auriferous gneiss is found at Batlow.

*Gold in Quartz Porphyry.*—At Bushy Hill, near Cooma, free gold occurs in crushed and foliated quartz porphyry. The rock is impregnated with iron pyrites, some of which is highly auriferous, and wherever the pyrites has been decomposed the gold is visible. This quartz-porphyry is almost identical in appearance and general characters with the rock in which the celebrated telluride of gold deposits occur at Kalgoorlie, in Western Australia. Up to the present time, however, no tellurium minerals have been found at Bushy Hill.

*Gold in Diorite.*—Gold occurs (in very small quantities) in pyrites in the diorite dykes and sills of the Lyndhurst Mines, near Carcoar. The occurrence of diorite dykes in proximity to many of our auriferous deposits points to the probability that the gold was in those cases derived from the diorites.

*Gold in Serpentine.*—On the eastern side of Jones' Creek, at Gundagai, a deposit of gold in serpentine was worked in the year 1881. The mine was opened on account of some fine veins of asbestos of unusual width. The gold was in the serpentine between two joints or walls, from six inches to a foot apart. The serpentine between the walls was foliated and fibrous in character, and the gold occurred in very fine films or plates, sometimes half an inch long, between the folia. The ore was treated in a battery, and yielded as much as two ounces of gold per ton, but the extraction caused a great deal of difficulty, as the mercury *sickened*, and there was probably a considerable loss in the tailings. The deposit was worked down to a depth of ninety feet, when the gold ran out, the last traces of it being seen in the wall. There are some fine specimens of the gold in serpentine from this mine in the Geological Museum attached to the Department of Mines in Sydney. Gold has also been seen in serpentine at Bingara.

*Gold in Felsite.*—Gold occurs in felsite in the Panbula and Wolumla Gold-fields. The first payable deposit was found at Mount Gahan, Panbula, in the year 1889. The felsite is of varying structure in different parts of the district; thus it occurs as rhyolitic felsite, nodular felsite (containing spherulites up to fourteen inches in diameter), dense horny felsite, brecciated felsite, and columnar felsite. The Panbula gold-field was examined and reported upon by Mr. J. E. Carne, Geological Surveyor. The following is an extract from his report:—"The most puzzling feature confronting the miners was the total absence of two defined walls to the auriferous deposits. In every instance one main wall alone was encountered; occasionally, for short distances, a fairly smooth and parallel face formed a deceptive foot or

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### 5. Irregular Deposits, or Bunches, of Auriferous Ironstone.

Bunches of auriferous iron ore occur at Mount Allen, about twelve miles from Mount Hope. These deposits were first opened on account of the ironstone, which was required as a flux for the siliceous copper ores of the New Mount Hope Copper-mining Company. Two of the bunches of iron ore had been worked out, and another was being opened in proximity to it, when one of the miners, thinking that gold might possibly be present, crushed and washed a sample of the ore, with the result that a good prospect was obtained. This was early in the year 1891, and the deposit has been held as a gold-mine since that date. The larger of the two bunches of iron ore, which were worked out before the presence of gold was suspected, measured about forty feet in length by about twenty in width, and its mean depth was about twenty feet. As the iron ore in this bunch was similar in appearance to that subsequently found to be auriferous, it is probable that it it also contained gold, and that the precious metal was alloyed with the copper produced by the New Mount Hope Copper-mining Company. The bunch in the Mount Allen Gold-mining Company's ground is of larger dimensions. It was opened as a quarry, and, at the surface, measured about sixty feet in length by about thirty in width. The deposit occurs in contorted slates, probably of Upper Silurian age, and the top of it cropped up under the summit of a roll or anticlinal fold of the strata. The slates in proximity to the ironstone were auriferous, the gold occurring in fine scales on the faces of the cleavage plains. The enrichment of the slates, however, does not appear to continue for any great distance from the ironstone. The iron ore consists chiefly of hematite, with a small percentage of magnetite, and one interesting feature in connection with it is, that it contains bismuth, in variable proportions, as well as gold. The first sample which was sent down for analysis contained 1·72 per cent. of oxide of bismuth ($Bi_2O_3$), but a careful sampling of the ore in the quarry was subsequently made by Mr. J. B. Jaquet, Geological Surveyor, and the mixed samples were analysed by Mr. J. C. H. Mingaye, with the following result:—

| | |
|---|---|
| Moisture at 100° C. ... ... ... | ·87 |
| Combined water ... ... ... ... | 4·15 |
| Ferric oxide ($Fe_2O_3$) ... ... ... | 74·11 |
| Ferrous oxide (FeO) ... ... ... | ·54 |
| Manganous oxide (MnO) ... ... | ·28 |
| Alumina ($Al_2O_3$) ... ... ... ... | 9·68 |
| Silica ($SiO_2$) ... ... ... ... | 9·60 |
| Lime (CaO) ... ... ... ... | ·14 |
| Magnesia (MgO) ... ... ... ... | ·10 |
| Phosphoric anhydride ($P_2O_5$) ... ... | ·26 |
| Sulphuric anhydride ($SO_3$) ... ... | ·03 |
| Bismuth oxide ($Bi_2O_3$) ... ... ... | ·25 |
| Copper oxide (CuO) ... ... ... | trace |
| | 100·01 |

It might be expected that the use of an ore containing bismuth as a flux for copper ores, would result in the production of brittle copper, and this was actually the case at the Mount Hope Copper-mine. It is probable, however, that the gold which found its way into the copper ingots fully compensated for the presence of the objectionable bismuth.

*Minerals Associated with Gold.*—The following is a list of the minerals with which gold is known to be associated in New South Wales, and the localities where they occur. Specimens of those marked with an asterisk can be seen in the Geological Museum, Sydney :—

| Mineral. | Locality. | Mineral. | Locality. |
|---|---|---|---|
| *Antimonite ... | Hillgrove. | Ilmenite ... ... | Inverell. |
| *Antimony (Native) | Lucknow. Koorawatha. | Limonite ... ... | Gundagai. |
| *Arsenic (Native)... | Lunatic. | *Magnetite ... | Mount Allen. |
| *Azurite ... ... | Cobar. | *Malachite... ... | Cobar. |
| Barytes ... ... | Krawarree. | *Mica ... ... | Hill End. |
| *Bismuthinite ... | Glen Innes. Nanima. | *Microcline ... | Mundi-Mundi (Barrier Ranges). |
| Bismutite... ... | ............ | *Mispickel... ... | Lucknow. Hill End. Nambucca. |
| *Blende ... ... | Fairfield. Grenfell. | *Molybdenite ... | Timbarra. Jingera. |
| *Bornite ... ... | Woodstock. | *Platinum ... ... | Fifield. |
| *Calcite ... .. | Ti-Tree Creek. Manilla. Solferino, &c. | *Pyrargyrite ... | Mount Drysdale. |
| *Chalybite... ... | Mt. Dromedary. | *Pyrites ... ... | Many localities. |
| *Chlorite ... ... | Bingara. | *Pyromorphite ... | Cullinga. Candelo. Wallendbene. |
| Chrysocolla ... | Barraba. | *Pyrrhotine ... | Gundagai. |
| *Common Opal ... | Wyalong. Brown's Creek. | *Quartz ... ... | Many localities. |
| *Copper (Native) ... | Wyalong. | Scheelite ... ... | Adelong. |
| *Copper Pyrites ... | Mitchell's Creek. | *Serpentine ... | Gundagai. Lucknow. Bingara. |
| *Cosalite ... ... | Duckmaloi River. | Silver (Native) ... | Billagoe. |
| *Fahlore ... ... | Mudgee. Major's Creek. | *Steatite ... ... | Bingara. Rockley. |
| *Galena ... ... | Scrub Yards. Grenfell. Yalgogrin. | *Talc ... ... | Rockley. |
| *Garnet ... ... | Brown's Creek. Barraba. | Telluride of Gold | Gundagai. |
| *Gypsum ... ... | Drake. Wyalong. | *Tetradymite ... | Oberon. Kentucky. Gundagai. Tamworth. |
| Hematite ... ... | Cobar. Mt. Allen. Drake. | Tourmaline ... | Shoalhaven. |
| *Horn Silver ... | Cobar. Billagoe. | Wollastonite ... | Brown's Creek. |

Gold occurred in extremely rich specimens, in calcite, in the Pioneer Reef, Ti-Tree Creek, near Barraba. In one instance 149 pounds of stone yielded fifty-eight ounces of gold. The occurrence of the rich gold was, however, very patchy.

Gold is found in massive copper-bearing sulphides, containing a small and variable proportion of bismuth, at Cobar. The association of gold and bismuth with copper ores in the Cobar Mine is of interest. For a considerable number of years this Company experienced much difficulty in refining their copper, owing to the presence of bismuth in the ore. The copper produced was sold to metal merchants in Germany, and while the vendors were very well satisfied with the price obtained for what they believed to be a rather inferior metal, the purchasers were making a good profit out of the gold which was alloyed with the copper, though its presence was, at that time, unknown to the proprietors of the mine. At the present time the sulphide ores in the Great Cobar Mine contain, on an average, from two and a half to three pennyweights of gold per ton, and about four per cent. of copper.

Gold also occurs in small quantities in massive iron and copper sulphides in the Lake George and Sunny Corner Mines.

The following is a list of minerals in the Geological Museum collection, in each of which visible fragments or grains of gold occurs:—

| Mineral. | Locality. | Mineral. | Locality. |
|---|---|---|---|
| Antimonite ... | Hillgrove. | Opal, Common ... | Wyalong.<br>Brown's Creek. |
| Arsenic (Native) ... | Lunatic. | Platinum ... ... | Fifield. |
| Blende ... ... | Fairfield. | Pyrargyrite ... | Mount Drysdale. |
| Bornite ... ... | Woodstock. | Pyrites (slickenside) ... | Wyalong. |
| Calcite ... ... | Ti-Tree Creek.<br>Manilla.<br>Rockley. | Pyrrhotine ... | Gundagai. |
| Chlorite ... ... | Bingara. | Quartz ... ... | Many localities. |
| Galena ... ... | Scrub Yards | Serpentine ... | Gundagai.<br>Bingara. |
| Gypsum ... ... | Wyalong. | Steatite ... ... | Bingara. |
| Limonite (pseudomorphs)... | Gundagai. | Tellurides ... | Oberon.<br>Tamworth.<br>Kentucky.*<br>Gundagai. |
| Microcline ... ... | Mundi-Mundi. | | |
| Mispickel ... ... | Lucknow.<br>Gundaroo. | | |

*Gold with Tellurium.*—The discovery in 1896, of the wonderful deposits of telluride of gold in Kalgoorlie (Western Australia), has led to much speculation as to whether similar ores do not occur in this Colony, and it has been represented that it is quite possible for such minerals to have been overlooked, in consequence of their general resemblance to some forms of pyrites and other well-known sulphides.

In a report to the Colonial Secretary, on the geological structure of the western slopes of the highlands of New England, dated 7th May, 1853, the late Rev. W. B. Clarke refers to the occurrence of (native?) tellurium at Bingara. He says:—"That metals exist in this gold-field, in more abundance than is supposed, is rendered probably by the abundance of iron which occurs there, by the existence of veins of carbonate of copper, and by the presence of tellurium, which is sometimes frequent in the gold washing. I believe it has been mistaken for rhodium, but this last named metal has, in some instances, the regular hexagonal form, and cannot be mistaken readily for that scarce and probably simple metal, rhodium."

Gold, associated with telluride of bismuth, has, during the last two or three years, been discovered in several localities in this Colony, such as Kentucky, Oberon, Tamworth, and Gundagai.

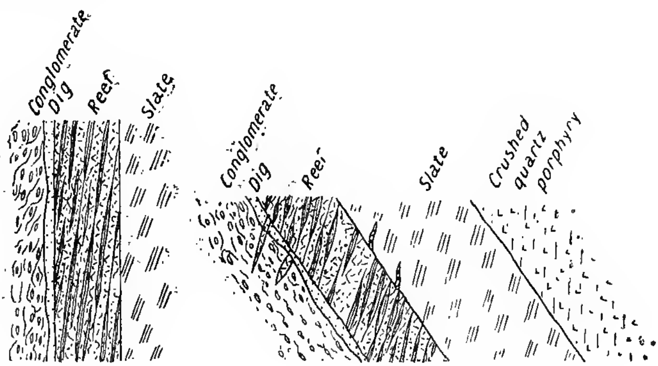
One of the products of decomposition of the telluride ores of Kalgoorlie is a substance locally known as *mustard gold.* It consists of free gold in an extremely fine state of division, and it has the appearance of dull yellow clay, until pressed with the blade of a knife, when it readily burnishes. A few months ago some mustard gold was discovered, by the Manager, in the Prince of Wales Mine, near Gundagai. It was similar to the Kalgoorlie mustard gold, except that its colour was orange red, instead of pale yellow. On being subjected to chemical tests the sample was found to contain tellurium and bismuth. Some samples of copper pyrites from the same mine were also tested, and the presence of tellurium, and bismuth, was also detected in these. Shortly afterwards some crystals of what was thought to be tetradymite (telluride of bismuth) were obtained in the 100 feet level, and free gold of a coarse character was associated with it. The same mineral, again associated with free gold, was afterwards recognised in the 300 feet level. About two grammes of the substance having been collected, a quantitative analysis was made by Mr. J. C. H. Mingaye, and proved it to be a new telluride mineral. The composition is as follows:—

| | |
|---|---|
| Bismuth (Bi) ... ... ... ... ... | 27 32 |
| Lead (Pb) ... ... ... ... ... ... | 14·17 |
| Gold (Au) ... ... ... ... ... ... | 7·72 |
| Silver (Ag)... ... ... ... ... ... | 2·15 |
| Tellurium (Te) ... ... ... ... ... | 47.12 |
| Selenium (Se) ... ... ... ... ... | minute trace |
| | 98·48 |

Unfortunately it has been impossible, so far, to obtain a further supply of the mineral.

As this occurrence is of peculiar interest, and as the Prince of Wales lode possesses some unusual features, a short description of the mine may not be out of place. It is situated about five miles to the north-west of the township of Gundagai. The country consists of coarse conglomerates and slates, with intrusive dykes of quartz porphyry, diorite, and serpentine. The quartz porphyries are foliated, and exhibit evidence of much crushing. They have, in fact, many features in common with rocks in which the tellurides of gold occur at Kalgoorlie. The conglomerates and slates also show signs of crushing; the latter are very much foliated, and the pebbles of the former are cracked, and, in many instances, sheared, one portion of a pebble sometimes overlapping, as much as a quarter of an inch, the other portion from which it has been sheared.

The reef occupies an irregular fissure between the crushed conglomerate, which forms its foot-wall, and a narrow belt of slate forming the hanging-wall; but sometimes the ore body is missing, and the slate lies directly against the conglomerate. A casing, or *dig*, of silicious clay from six inches to two feet wide occurs on the foot wall of the lode.

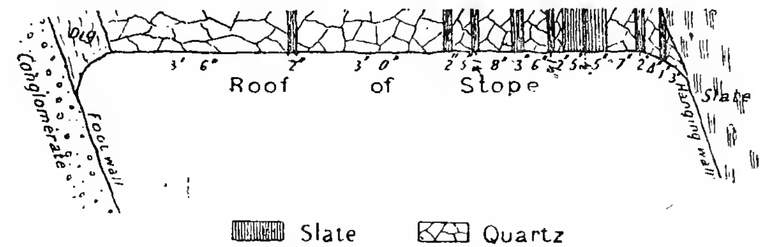



Plan . Vertical cross section.

SKETCH PLAN AND SECTION OF THE PRINCE OF WALES REEF, GUNDAGAI.

The reef, in strike, has a curved course, following approximately the contour of the hill; the strike, therefore, varies from N. 18° W., to N. 38° W., and the dip is north easterly at 55°. The width of the lode varies from four to thirty feet, and its mean width is about twelve feet. It is made up of lenticular masses of quartz, separated by numerous decomposed slate masses, or *horses*, of similar form. The direction of these lenses of slate and quartz is diagonal across the lode, at a slight angle with the walls, as shown in the sketch plan above. These lens-shaped masses also have a northerly dip at an angle of 20°. In places the slate masses are only a few inches apart in cross section, while occasionally there are very few of them, and the lode is almost entirely made up of quartz.

A measurement in the roof of the 200 feet level at one spot gave the following section :—




Small lenticular veins of quartz drop from the foot-wall, and rise from the hanging-wall at intervals, as shown in the cross section. These veins are generally much richer in gold than the body of the lode, and yield as much as nine ounces per ton. Some of the veins that drop from the foot-wall cut right through the dig, or casing, while others do not, but start in the conglomerate. Copper pyrites occurs occasionally in small bunches in the quartz, and whenever this is found it is regarded as an indication of enrichment in gold contents. The whole width of the lode (from four to thirty feet), including the lenticular patches of slate, is extracted and crushed, and at the present time the ore is yielding rather over half an ounce per ton ; the gold, however, occurs in *chutes*, and no auriferous ore has yet been won below the 300 feet level. The gold is worth £3 16s. per ounce.*

It would appear as if the slates, owing to lateral earth movements, have been torn or split diagonally (in the direction of their folia), when the fissure was formed at the junction of the slate and conglomerate, and that this irregular fissure has been subsequently filled with quartz, which has therefore surrounded the lens-shaped masses of slate and enclosed them in the lode. The maximum width of the belt of slate, where it has been exposed by crosscuts, is about twenty-five feet.

*Depth of Workings in Auriferous Deposits.*

The following list shows the depth of the workings in eight of the deepest gold mines in New South Wales. :—

| | |
|---|---|
| Great Victoria G. M. Co., Adelong (nearly vertical shaft) ... ... ... ... | 1,140 feet (vertical depth). |
| Wentworth Gold-fields Proprietary Co., Lucknow ... ... ... ... ... | 1,000 feet (vertical depth of workings). |
| Darcy Estates G. M. Co. Lucknow ... ... | 1,000 feet (vertical shaft). |
| West Sunlight G. M. Co., Hillgrove ... | 1,000 feet (vertical shaft). |
| Baker's Creek G. M. Co., Hillgrove... ... | †1,000 feet (vertical shaft). |
| Aladdin's Lamp G. M. Co., Lucknow ... | 940 feet (vertical depth of workings). |
| Bushman's Hill G. M. Co., Parkes ... ... | 925 feet (inclined shaft). |
| Sunlight G. M. Co., Hillgrove ... ... | 900 feet (vertical depth of workings). |

* Since the above was written the workings in the Prince of Wales Mine have been carried to a greater depth and the ore has become poorer, being now worth only about five pennyweights per ton.

† The bottom of the shaft is 1,300 feet below the outcrop of the veins on the side of the gorge ; the veins have been worked by tunnels for a vertical height of 300 feet above the mouth of the shaft.

Native gold is never absolutely pure, being always alloyed with a greater or less proportion of silver, together with traces of other metals. The following table, showing the average assay and value of gold from the various gold-fields of New South Wales, as received at the Sydney Branch of the Royal Mint during the year 1898, has been kindly prepared by E. H. S. Von Arnheim, Esq., Deputy Master :—

| Districts and Divisions. | | Number of Samples. | Loss per cent. in milling. | Average Assay (Decimal). Gold. | Average Assay (Decimal). Silver. | Average value* per ounce, after milling. £ s. d. |
|---|---|---|---|---|---|---|
| Northern | Tamworth ... ... | 6 | 3·35 | ·9310 | ·061 | 3 19 2 |
| | Bingara ... ... | 6 | 6·28 | ·8966 | ·092 | 3 16 4 |
| | Tenterfield ... ... | 6 | 2·49 | ·8740 | ·115 | 3 14 5 |
| Southern | Braidwood and Araluen | 6 | 1·59 | ·9375 | ·054 | 3 19 9 |
| | Nerrigundah ... ... | 6 | 1·32 | ·9821 | ·011 | 4 3 5 |
| | Adelong ... ... | 1 | 3·60 | ·9215 | ·065 | 3 18 4 |
| | Tumut ... ... | 4 | 3·81 | ·9395 | ·053 | 3 19 11 |
| | Tumbarumba... ... | 7 | 3·10 | ·9399 | ·053 | 3 19 11 |
| | Gundagai ... ... | 6 | 7·31 | ·9594 | ·034 | 4 1 7 |
| | Cooma... ... ... | 6 | 3·04 | ·9465 | ·047 | 4 0 5 |
| Western | Bathurst ... ... | 6 | 2·51 | ·9323 | ·059 | 3 19 3 |
| | Carcoar ... ... | 6 | 4·20 | ·8920 | ·086 | 3 15 11 |
| | Orange ... ... | 6 | 3·52 | ·9390 | ·053 | 3 19 10 |
| | Hill End ... ... | 6 | 1·93 | ·9431 | ·047 | 4 0 3 |
| | Sofala ... ... ... | 6 | 1·83 | ·9310 | ·060 | 3 19 2 |
| | Mudgee ... ... | 6 | 1·41 | ·9379 | ·055 | 3 19 9 |
| | Gulgong ... ... | 4 | 1·67 | ·9332 | ·060 | 3 19 4 |
| | Wellington ... ... | 8 | 2·42 | ·9459 | ·046 | 4 0 5 |
| | Parkes and Forbes ... | 7 | 3·07 | ·9047 | ·078 | 3 17 0 |
| | Grenfell ... ... | 2 | 4·46 | ·9449 | ·047 | 4 0 4 |
| | Young ... ... | 4 | 1·89 | ·9561 | ·037 | 4 1 4 |
| | Tibbooburra ... ... | 6 | 1·87 | ·9692 | ·023 | 4 2 4 |
| | Windeyer ... ... | 6 | 1·35 | ·9350 | ·057 | 3 19 6 |

* Gold reckoned at £3 17s. 10½d. the ounce standard; silver at 1s. 6d. the ounce fine.

## Brief Summary of the Geological History of the Gold Deposits of New South Wales.

From a study of the geology of this Colony, and of the gold deposits generally, the following inferences may be drawn :—

Gold made its first appearance in the rocks now forming the surface, and the auriferous (and other metalliferous) lodes were formed, prior to the commencement of the Permo-Carboniferous period.

After the deposition of the Silurian formations, the latter were subjected to intrusions of granite, felspar porphyry, and other igneous rocks. The effect of these intrusions was to violently disturb the Silurian sediments; the originally horizontal strata were thrown into vertical positions in some places, and bent or folded into anticlinal and synclinal curves in others. As a direct result of this rupturing and crumpling of the rocks, fissures were formed across the beds, and open spaces between them. Thermal waters from below, carrying silica, gold, and other metals, in solution, found their way into the fissures, and, under the influence of reduced pressure, deposited therein quartz, gold, and other minerals, thus forming lodes, such as those at Hill End, Cobar, Mount Brown, and many other places. A similar series of occurrences took place at the close of the Carboniferous period, resulting in the formation of the auriferous (and other metalliferous) lodes which intersect the blue claystones at Bingara, Copeland, Nana Creek, etc.

No sooner had the lodes been formed than their destruction commenced, and this destructive process has been in operation ever since. The denuding agencies of the atmosphere gradually but surely wore down the surface of the rocks and of the lodes which intersected them. The fragments of quartz, gold, etc., set free by these abrading influences, were washed down by the rain to lower levels, becoming rounded and waterworn during their transit; in the beds of creeks and rivers they were subjected to a natural process of sluicing, and the gold was more or less concentrated in what are termed alluvial drifts, or *leads*. These drifts were then covered by thick deposits of sand and clay, derived from the denudation of granite, sandstones, slates, etc.; and, in many cases, in Tertiary times, the valleys were invaded by streams of molten lava, which, when consolidated, formed an additional and durable covering to the auriferous deposits.

Although traces of detrital gold have been discovered in practically all the geological formations which have been laid down since the close of the Carboniferous period, payable deposits appear to be confined to a few of them.

The oldest payable alluvial deposits hitherto worked occurred at Tallawang, near Mudgee, where the conglomerates forming the base of the Upper Coal Measures (Permo-Carboniferous), yielded from one to fifteen penny-weights of gold per ton.

In Middle Cretaceous times auriferous river drifts were deposited on the flanks of Mount Brown, and at Tibbooburra, and these have been extensively worked for gold. An alluvial conglomerate of Cretaceous age has also been worked at the Peak, between Kayrunnera and Tarella.

At Gulgong, Forbes, Parkes, Tumbarumba, Rocky River, and other localities, river drifts of Tertiary (Pliocene) age, have been found to contain very rich deposits of detrital gold. Many of these *leads* are covered by a considerable thickness of basalt, and they are known amongst miners as *deep leads*.

Lastly, on most of the Gold-fields of the Colony, Post Tertiary (Pleistocene and Recent) alluvial deposits have yielded very large quantities of detrital gold on the surface, or at comparatively shallow depths; and many of the rivers now flowing through the country contain in their gravels gold which has been derived from the wearing down of older drifts.

## Production of Gold.

It will be noticed, on referring to the appended statistical table, that a marked increase in the production of gold occurred in the year 1894, and that the increased yield has been fairly well maintained during the succeeding years. This improvement was brought about in the following way: Owing to the financial depression which overtook the Colony in 1893, very many persons were thrown out of employment in the city, and numbers of these, although trained to commercial pursuits, and accustomed to city life, travelled into the country and turned their attention to gold-prospecting. About this time there was great distress amongst the labouring classes also; and the Government, with a view of providing work for the unemployed, offered inducements to them to prospect for gold. They gave each applicant a free railway pass to whichever gold-field he desired to try his luck upon, and in addition provided him with a set of tools and a fortnight's rations.

While it is probable that this liberal treatment was abused in a few cases, there can be no doubt that the result more than justified the policy of the Government. Employment was found for many who were without the means of existence in Sydney. There was also an immediate increase in the production of gold; and by these means the Colony was assisted, to a large extent, in tiding over a very critical period in its history.

Table showing the Quantity and Value of Gold won in the Colony of New South Wales from 1851 to 1899.

| Year. | Quantity in ounces. | Value. | | | Year. | Quantity in ounces. | Value. | | |
|---|---|---|---|---|---|---|---|---|---|
| | | £ | s. | d. | | | £ | s. | d. |
| 1851 | 144,120 | 468,336 | 0 | 0 | 1876 | 167,411 | 613,190 | 7 | 9 |
| 1852 | 818,751 | 2,660,946 | 0 | 0 | 1877 | 124,118 | 471,448 | 8 | 1 |
| 1853 | 548,052 | 1,781,172 | 0 | 0 | 1878 | 119,710 | 430,200 | 5 | 4 |
| 1854 | 237,910 | 773,209 | 0 | 0 | 1879 | 109,649 | 407,218 | 13 | 5 |
| 1855 | 171,367 | 654,594 | 0 | 0 | 1880 | 119,322 | 444,252 | 10 | 7 |
| 1856 | 184,600 | 689,174 | 0 | 0 | 1881 | 151,512 | 573,581 | 11 | 3 |
| 1857 | 175,949 | 674,477 | 0 | 0 | 1882 | 140,469 | 526,521 | 12 | 5 |
| 1858 | 286,798 | 1,104,174 | 12 | 2 | 1883 | 123,811 | 458,530 | 4 | 3 |
| 1859 | 329,363 | 1,259,127 | 7 | 10 | 1884 | 107,403 | 396,059 | 2 | 8 |
| 1860 | 384,053 | 1,465,372 | 19 | 9 | 1885 | 103,736 | 378,665 | 0 | 3 |
| 1861 | 465,685 | 1,806,171 | 10 | 8 | 1886 | 101,416 | 366,294 | 7 | 7 |
| 1862 | 640,622 | 2,467,779 | 16 | 1 | 1887 | 110,288 | 394,578 | 16 | 3 |
| 1863 | 466,111 | 1,796,170 | 4 | 0 | 1888 | 87,541 | 317,240 | 15 | 9 |
| 1864 | 340,267 | 1,304,926 | 7 | 11 | 1889 | 119,949 | 434,784 | 6 | 1 |
| 1865 | 320,316 | 1,231,242 | 17 | 7 | 1890 | 127,760 | 460,284 | 16 | 2 |
| 1866 | 290,014 | 1,116,403 | 14 | 5 | 1891 | 153,583 | 559,231 | 2 | 3 |
| 1867 | 271,886 | 1,053,578 | 2 | 11 | 1892 | 158,502 | 575,298 | 16 | 1 |
| 1868 | 255,662 | 994,665 | 0 | 5 | 1893 | 179,288 | 651,285 | 15 | 8 |
| 1869 | 251,491 | 974,148 | 13 | 4 | 1894 | 324,787 | 1,156,717 | 7 | 7 |
| 1870 | 240,858 | 931,016 | 8 | 6 | 1895 | 360,165 | 1,315,929 | 5 | 4 |
| 1871 | 323,609 | 1,250,484 | 15 | 11 | 1896 | 296,072 | 1,073,360 | 4 | 7 |
| 1872 | 425,288 | 1,644,176 | 19 | 5 | 1897 | 302,817 | 1,128,163 | 15 | 0 |
| 1873 | 362,104 | 1,396,374 | 11 | 4 | 1898 | 340,493 | 1,244,329 | 15 | 1 |
| 1874 | 271,166 | 1,041,614 | 5 | 9 | 1899 | 496,196 | 1,751,815 | 0 | 0 |
| 1875 | 230,882 | 877,693 | 18 | 0 | | 12,862,922 | 47,546,012 | 5 | 5* |

* These values are based on the assays of the gold in every instance.

# PLATINUM.

PLATINUM is an almost silver-white metal which is found in a native state alloyed with iron, iridium, osmium, and other rare metals. It usually occurs in grains or scales, sometimes in irregular lumps or nuggets, and rarely in crystals. A cubical crystal of platinum found at Fifield, and now in the Geological Museum, measures three-sixteenths of an inch (nearly).

The hardness of native platinum is from 4 to 4·5, and its specific gravity varies from 14 to 19, according to the proportion of other metals alloyed with it; but the specific gravity of purified platinum is about 21·5. It is infusible except at very high temperatures (about 2,000° C. before the oxy-hydrogen blowpipe), is unacted upon by ordinary acids, but is soluble in hot nitro-hydrochloric acid. Compact platinum does not amalgamate with mercury in the cold, so that it can easily be separated from gold by means of mercury.

The only other form in which platinum is found is that of an arsenide in the mineral sperrylite which occurs in minute cubes or cubo-octahedral crystals which have a tin white colour and black streak. Sperrylite contains 43·5 per cent. of arsenic and 56·5 per cent. of platinum together with very small quantities of antimony and rhodium. Its hardness is 6–7, and its specific gravity 10·6.

*Uses of Platinum.*—The metal is largely used in chemical processes in the form of crucibles, dishes, spoons, spatulas, foil, and wire. Its indestructibility, its high melting point, and its insolubility in ordinary acids render it invaluable to the analytical or manufacturing chemist.

The coefficient of expansion of platinum is nearly the same as that of glass, and hence the metal has been largely employed in the construction of incandescent electric lamps for the purpose of connecting the outside copper wire with the carbon filament. Platinum is also extensively used in the manufacture of the contact points of telegraph keys.

Another important use for platinum, particularly in the United States, is connected with dentistry; the pins by which artificial teeth are attached to the plate are constructed of platinum, as it is the only metal known to be suitable for the purpose, and will remain unaltered at the high temperature at which the teeth have to be baked.

In the manufacture of sulphuric acid the stills, used for the concentration of the crude acid, are made of platinum alloyed with about three per cent. of iridium.

Platinum is also used to some extent in jewellery; but the quantity required for this purpose varies according to changes of fashion.

Other uses are in the manufacture of platinotype paper for printing photographs; in the construction of fine weights for chemist's balances; for surgical and other scientific instruments; for making balance-wheels and hair-springs of non-magnetic watches; for obtaining a silver colour on porcelain; for platinum plating; for producing so-called "oxidised silver"; and for the fuses of electrically exploding dynamite cartridges.

*Platinum in New South Wales.*—The similarity between the older rocks of the Cordillera of New South Wales and those of the Ural Mountains of Russia, induced Sir Roderick Murchison, in 1844, to predict the discovery of gold in this Colony.* The same evidence might have led to the inference that platinum would also be found here, and, as a matter of fact, it is now known to occur in several widely separated districts of the Colony, though the platinum mining industry, judged by the quantity of metal hitherto produced, is unimportant in comparison with that of gold-mining. On the other hand, it must be borne in mind that the most productive deposit of platinum in New South Wales was discovered only recently, and it is not unreasonable to expect that others will be found, so that this branch of mining may yet assume large proportions.

The earliest record we have of the occurrence of platinum in the Colony is contained in a report by Mr. S. Stutchbury to the Colonial Secretary, referring to an examination of the country in the neighbourhood of the Macquarie and Turon Rivers. The report is dated from Orange, June 9th, 1851, and in it Mr. Stutchbury says, "I have seen a few grains of platina, but it appears to be rare."

The Rev. W. B. Clarke made the following remarks in his book "The Southern Gold-fields," published in 1860:—"Small particles of a white mineral, extremely hard and of a very high specific gravity, frequently occur in the same (Northern and Southern gold-fields) alluvia. Some of them I have found to be *platinum*, others are, undoubtedly *native iridium*, the colour, gravity, hardness, crystallisation, lustre, &c., all agreeing with the known composition of that mineral."

In his book entitled "Minerals of New South Wales," Professor Liversidge states that platinum is "reported to occur with gold in the Shoalhaven River, county of Dampier; in the Ophir gold district, county of Wellington; in the form of small grains at Bendemeer, county of Inglis; and at Calton Hill, Dungog, in the Hunter and Macleay district, county of Durham. A small nugget, weighing 268 grains (also stated as weighing $1\frac{1}{3}$ oz.), and having a specific gravity of between 15 and 16, was obtained from Wiseman's Creek, county of Westmoreland, with alluvial gold. Platinum has been obtained in small quantity in the washings from the Aberfoil River, about fifteen miles from Oban, associated with metallic tin, gold, iridosmine, cassiterite, sapphires, topaz, &c."

* Gold had, however, been discovered prior to that date, though Murchison was not aware of the fact.

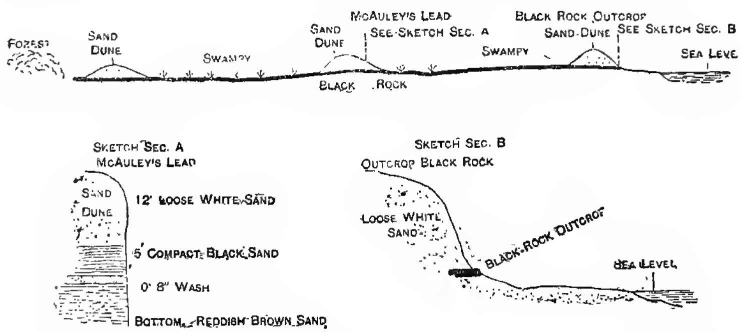
## Platinum-bearing Sands of the Northern Beaches.

On page 8, reference was made to the auriferous beach sands of the northern coast, which has been worked by beach-combers since the year 1870. The metallic contents of these sands are concentrated by waves of the sea during heavy weather, and mining operations have, consequently, only been carried on intermittently. The fact that these sands

1878. contain platinum as well as gold, was not discovered until 1878. In that year a sample of the sand was assayed by Mr. W. A. Dixon, F.C.S. (at that time Analyst to the Department of Mines), and the following return was obtained, viz. :—

| | dwt. | grs. | |
|---|---|---|---|
| Gold ... ... | 1 | 5 | per ton. |
| Platinum—less than 5 grains. | | | |

The beach-sand deposits of the Evans River were examined and reported upon in 1894 by Mr. G. A. Stonier, and those of the Esk River and Jerusalem Creek (in the same district), in 1896, by Mr. J. E. Carne.




Sketch Section of the Auriferous and Platiniferous Beach Sands of the Northern Coast.

(After J. E. Carne.)

The metals, &c., which are concentrated on the present beaches during stormy weather, are brought down by the action of the waves, from an ancient beach deposit, which occurs at an elevation of about six feet, and which has received the name of *black-rock* locally. This consists of a layer or bed of black sand-rock, composed chiefly of small zircons, with some grains of ilmenite (titaniferous iron), quartz, garnet, and tinstone, and also small but variable proportions of platinum, platinoid metals, and gold in a very finely divided state. The black colour of the sand-rock is due to organic matter, probably derived from swamp vegetation.

The ultimate source of the precious metals is not known, but it is probable that, before being deposited in the *black-rock*, they existed, in a detrital state, in a Tertiary quartz pebble drift, which occurs, under basalt, along this coast, and which has undergone a considerable amount of denudation.

*Method of Working the Ancient Beach Deposits.*—As the *black-rock* is covered by an overburden of from three to sixteen feet of blown sand, this has first to be stripped by manual labour. This work is done in paddocks or benches of a convenient size. The *black-rock* is then removed in successive benches, each worked-out bench being used as a dump for the overburden stripped from the next paddock. The worked-out benches are also employed as well-holes for draining off the water from the *black-rock* before it is excavated from adjoining areas.

*Method of Treatment of the Ore.*—The *black-rock* is crushed with wooden mallets, and passed through screens of quarter-inch mesh; the rejected portion is broken under a roller until it will all pass through the screen. The fine material is then conducted, in a state of suspension in water, over inclined tables covered with strips of carpet, or cocoa-nut matting. These tables are fourteen feet long, two feet three inches wide, and are inclined at an angle of thirteen degrees. The strips of carpet are washed from time to time in a tub of water in order to collect the concentrated material caught upon them. At the end of a month's run the accumulated concentrates are washed in an alkaline solution, containing about three pounds of washing soda and a quarter of a pound of caustic soda in five gallons of water. The object of this process is to remove the organic matter, and leave the grains of gold with clean surfaces, so that they may be easily amalgamated. The cleaned concentrates are next passed several times over tables covered with amalgamated copper-plates, which retain the gold. The balance of the concentrates, or that portion which escapes from the copper-plates, is stored in heaps as it contains the platinum and tinstone, as well as particles of amalgam, and some free gold which has not been caught on the tables.

Several samples of concentrates, after passing over the copper-plates, and also samples of tailings from the carpet-covered tables, have been assayed by Mr. J. C. H. Mingaye, F.C.S., and the results are given below.

Mixed tailings from about two-thirds of McAuley's Lead claims:

| | dwt. | grs. |
|---|---|---|
| Gold ... ... ... ... ... ... ... | 2 | 14 |
| Silver... ... ... ... ... ... ... | 1 | 7 |
| Metallic tin ... ... ... ... ... ... | 0·05 per cent. | |

Tailings from Hammond, Dowling, and Party's claim:

| | dwt. | grs. |
|---|---|---|
| Gold ... ... ... ... ... ... ... | 3 | 19 |
| Silver... ... ... ... ... ... ... | 3 | 19 |

Concentrates from McAuley's Lead claims, after amalgamation:

| | oz. | dwt. | grs. |
|---|---|---|---|
| Gold ... ... ... ... ... ... | 2 | 19 | 3 |
| Platinum ... ... ... ... ... | 0 | 18 | 17 |
| Iridosmine ... ... ... ... ... | under | | 15 |
| Metallic tin ... ... ... ... ... | 5·12 per cent. | | |

Concentrates from Hammond, Dowling, and Party's claim, after passing three times over amalgamated plates:

| | oz. | dwt. | grs. |
|---|---|---|---|
| *Gold ... ... ... ... ... ... | 15 | 1 | 12 |
| Platinum ... ... ... ... ... | 2 | 18 | 3 |
| Iridosmine ... ... ... ... ... | 0 | 17 | 7 |
| Metallic tin ... ... ... ... ... | 28·52 per cent. | | |

* Chiefly from amalgam which escaped from plates.

Concentrates from J. Ware's claim, Richmond River District:

| | oz. | dwt. | grs. |
|---|---|---|---|
| Gold ... ... ... ... ... ... | 0 | 9 | 11 |
| Platinum ... ... ... ... ... | 129 | 9 | 16 |
| Osmiridium ... ... ... ... ... | 58 | 0 | 7 |
| Iridium and other platinoid metals ... | 5 | 0 | 7 |

Concentrated beach-sand from Ballina:

| | oz. | dwt. | grs. |
|---|---|---|---|
| Gold ... ... ... ... ... ... | 2 | 19 | 12 |
| Platinum ... ... ... ... ... | 428 | 9 | 4 |
| Iridium ... ... ... ... ... | 26 | 16 | 16 |
| Osmiridium ... ... ... ... .. | 161 | 13 | 20 |
| Other platinoid metals ... ... ... | 2 | 16 | 11 |

Concentrated beach-sand from Richmond River:

| | oz. | dwt. | grs. |
|---|---|---|---|
| Platinum, at the rate of ... | 1166 | 13 | 10 per ton. |

Concentrated platiniferous sand from Richmond River:

| | | oz. | dwt. | grs. |
|---|---|---|---|---|
| Platinum ... | 3·58 per cent. = | 1169 | 8 | 20 per ton. |

It should be remarked, however, that no large parcels of rich concentrates were prepared; the last three analyses quoted above refer to small samples which had been very carefully concentrated by hand.

So far as can be ascertained from the records, only 60 ounces of platinum from the beach-sands were actually disposed of, viz., in the year 1894, and the price obtained was £240.

1889. *Platinum deposits in the Broken Hill district.*—In the year 1889, several samples, supposed to contain silver-lead ore, from the Broken Hill district, were forwarded, by a local resident, to the Department of Mines, for assay. On being examined by the Analyst. Mr. J. C. H. Mingaye, these samples were found to contain platinum, The determinations were as follow :

| | oz. | dwt. | grs. | |
|---|---|---|---|---|
| (1) Ochreous felspathic lodestuff .. | 1 | 9 | 9 | platinum per ton |
| (2) Compact ferruginous claystone ... | | 6 | 12 | ,, ,, |
| (3) Ferruginous felspathic rock with green carbonate of copper ... | strong trace | | | ,, |

Mr. Mingaye noted that the platinum occurs, associated with the metals which usually accompany it, in a very fine state disseminated
1891. through the ore. Again, in June, 1891, Mr. Mingaye reported the presence of platinum in felsitic and granitic rock from the same district, and an assay of the material yielded at the rate of four pennyweights of the metal per ton. Six months later bulk samples of the same ore were obtained, with the object of ascertaining whether it would be possible to concentrate it. It was crushed and passed over Frue vanners at the Clyde Metallurgical Works ; duplicate assays were then made of 10,000 grain samples of the concentrates.

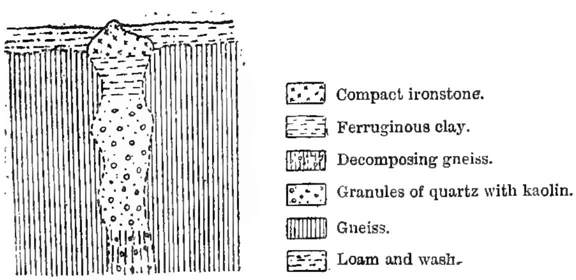
In the first trial 1 ton 1 cwt. of ore (which contained platinum at the rate of 1 dwt. 15 grs. per ton) yielded 26 lb. of dry concentrates, which assayed at the rate of 9 dwt. 18 grs. of platinum per ton.

In the second attempt 17½ cwt. of ore yielded 66 lb. of dry concentrates containing at the rate of 16 dwt. 7 grs. of platinum per ton.

A qualitative analysis showed that the concentrates in each case contained the following substances in addition to platinum and platinoid metals :—Lead, zinc, antimony, arsenic, gold, silver, bismuth (a trace), silica, alumina, oxide of iron, lime, magnesia, sulphuric acid, carbonic acid, &c.

It was reported that Messrs. Johnston, Matthey, & Co., of London, found platinum in a number of samples forwarded to them, from Broken Hill, in amounts varying from a few pennyweights to two and a half ounces per ton.

1892. In 1892, Mr. J. B. Jaquet, Geological Surveyor, furnished a report on these deposits. He found that ore carrying a small proportion of platinum could be obtained over a very wide area of the Broken Hill District, but that prospecting for the metal had been confined to two localities, viz., at Little Darling Creek, Parish of Tara, and at Mulga Springs, Parish of Moorkaie, these two places being distant about seven miles from each other. In both localities the country consists of gneisses, schists, and quartzites, representing highly-altered sedimentary rocks, probably of Lower Silurian age. These rocks are intruded by dykes and bosses of very basic diorite, and by granite; while at a distance of six miles from Little Darling Creek a boss of serpentine occurs. Scattered over the country are superficial masses of ironstone generally more or less impregnated with carbonate of copper. These masses have a regular trend for a short distance, but more often they are quite irregular, and none of them can be traced over a wide area. They are found capping altered sedimentary and intrusive rocks alike, and no definite law seems to govern their distribution, but in a number of cases they occur at the junction of a compact rock with one of looser texture. It is in these deposits of ironstone, and the more or less decomposed rock underneath them, that the platinum occurs. All the superficial deposits of ironstone do not contain platinum, and no difference can be detected in the appearance of those ironstones in which the metal is present, and those in which it is absent. Occasionally the ironstone is seen cropping up at the surface, but it is generally covered by shallow Pleistocene and recent deposits, and trenching is necessary to discover it.




Sketch Section of Platiniferous Deposit.

(After J. B. Jaquet.)

The ironstone cap passes by insensible gradations into ferruginous clays below, and these clays into granules of silica, cemented together with kaolin, or into a compact kaolin. The siliceous kaolin passes into a decomposing felspathic rock, which may be either gneiss or a portion of a granitic dyke. Defined walls never occur, the platinum-bearing ore gradually passing into the rocks containing it. It would appear from the assays that the clays and kaolin contain a larger amount of platinum than the ironstone. The greatest vertical depth penetrated in any of the prospecting shafts was thirty-two ft. When the copper-stained ironstone cap, and the clays immediately below it, are passed through, no traces of sulphides of copper or iron are to be seen, so that the cap is not a gossan representing the oxidised portion of ore beneath. Again, the platinum-bearing rock has most irregular boundaries, and nothing like defined walls are ever present. These circumstances appear to show that there is no analogy between these deposits and metalliferous lodes. Finally, Mr. Jaquet states that they probably owe their origin to springs. The iron, copper, platinum, and small quantities of other metals were, probably, carried in solution by these springs. The iron and copper were precipitated when they reached the surface, and were brought under the oxidising influence of the atmosphere, but the platinum seems to have been partially absorbed by the kaolin, and only a portion of it reached the surface.

As showing the extremely fine state of division in which the platinum exists in these ores, it may be stated that in no instance has a particle of the metal ever been detected by the eye.

*Alluvial Deposits of Platinum at Fifield.*—The presence of platinum in the auriferous drifts around Fifield, which town is situated about fifty-four miles to the north-west of Parkes, was not recognised until the year 1887, when samples of it were discovered by Mr. J .F. Connelly, and presented to the Geological Museum. Mining operations in this district, however, were only carried on in a desultory kind of way until 1893, when a rush took place, on the discovery, by Messrs.
1893. Fifield, Rand, and Party, of a new *lead*, carrying gold and platinum, in the vicinity of the present town of Fifield, which was named after the prospector. The platiniferous deposits of this district have also been described by Mr. J. B. Jaquet.

The country around Fifield consists of Silurian slates with sandstones and limestones of Devonian, or Siluro-Devonian age. The Silurian slates are intruded by dykes of diorite. The township of Platina is about two miles from Fifield, and the deep alluvial *lead*, containing platinum and gold, extends from near the former place for over a mile in length, and varies from sixty to one hundred and fifty feet in width. The sinking is from sixty to seventy feet, through loam, with some bands of barren quartz drift. The platinum and gold occur in fairly coarse waterworn grains, and, as a rule, are confined to the cavities in the bed-rock, and to the washdirt for a few inches above it. Occasional nuggets of platinum have been obtained ; the largest hitherto found weighs 27 dwt., and was purchased for the Geological Museum Collection. There are two other nuggets in the Museum weighing eleven and eight pennyweights respectively.

The washdirt contains from five to twelve pennyweights of platinum, and from one to three pennyweights of gold, per ton. The yield from 269 loads, taken from a number of claims along the *lead*, was at the rate of 6 dwt. 21 grs. of platinum, and 1 dwt. 23 grs. of gold per ton. The total production of crude platinum from this field up to the end of December, 1898, was 5,654 ounces.

An analysis of the crude platinum from Fifield, made by Mr. H. P. White, F.C.S., Assistant Analyst to the Department of Mines, shows that it is of very fair quality. The analysis yielded as follows :—

| | |
|---|---|
| Platinum ... ... ... ... ... ... | 75·90 |
| Iridium ... ... ... ... ... ... | 1·30 |
| Rhodium ... ... ... ... ... ... | 1·30 |
| Palladium ... ... ... ... ... ... | traces |
| Osmiridium ... ... ... ... ... ... | 9·30 |
| Iron ... ... ... ... ... ... .. | 10·15 |
| Copper ... ... ... ... ... ... | ·41 |
| Gold ... ... ... ... ... ... ... | nil |
| Lead ... ... ... ... ... ... ... | traces |
| Siliceous matter .. ... ... ... ... | 1·12 |
| | 99·48 |

*Treatment of the Washdirt.*—A few inches of the soft bed-rock is extracted with the washdirt, and as this is of a clayey nature the washdirt is first treated in puddling-machines, worked by horse-power. In this process the decomposed slates are disintegrated, and the gravel containing the platinum and gold is rendered fit for sluicing; this latter operation is then conducted in ordinary sluice-boxes, and the gold is finally separated from the platinum by amalgamation with mercury.

*Origin of the Platinum.*—In the neighbourhood of Fifield and Platina, a series of conglomerates and shales occur, which are probably of Tertiary age. The conglomerates consist of round and subangular quartz pebbles, cemented together by peroxide of iron. On a low hill called "Jack's Look-out," about two miles from Fifield, waterworn grains of gold and platinum have been found in this cement or conglomerate, and a specimen of the cement containing a fragment of platinum may be seen in the Geological Museum. Moreover, boulders of this conglomerate are found in the Fifield-Platina alluvial *lead*, so that there can be little doubt that the metals have been directly derived from the conglomerate, owing to the denudation of the latter. The original source of the gold and platinum, however, has yet to be found. No reefs or lodes which could have formed their matrix appear to exist anywhere in the neighbourhood. One point, however, appears to be certain, viz., that the gold and platinum have had a common origin, for a specimen has been found in the *lead* showing the two metals in contact with one another, and apparently inseparable. This specimen is now in the Geological Museum. It is well waterworn, and weighs 4·2 grains; there is no trace of quartz or other gangue adhering to it. The metal gold is, however, known to occur disseminated through igneous rocks, as well as in quartz reefs; so that, unfortunately, this remarkable specimen does not help us to determine what was the original matrix of the platinum.

The chief difficulty in connection with the platinum mining industry in this district is the scarcity of water. The rainfall is small, and prolonged droughts are of common occurrence; operations have therefore to be frequently suspended for long intervals.

The country in the neighbourhood of Fifield is generally of a very flat character, and the surface consists of Pleistocene clays, which obscure the geological features, and render prospecting for new *leads* a matter of much difficulty. There is reason, however, to expect that other similar deposits will be found in the district, for at Burra Burra, about ten miles north-east of Fifield, a drift has been worked containing platinum associated with gold and tinstone.

*Production of Platinum.*

The following table shows the production of platinum from 1894 to 1899, inclusive, most of the metal having been obtained from the Fifield deposits :—

| Year. | Quantity in Ounces. | Value. |
|---|---|---|
| | | £ |
| 1894 ... ... ... ... | 1,060 | 1,390 |
| 1895 ... ... ... ... | 413 | 475 |
| 1896 ... ... ... ... | 2,438 | 3,479 |
| 1897 ... ... ... ... | 1,966 | 2,949 |
| 1898 ... ... ... ... | 1,250 | 2,062 |
| 1899 ... ... ... ... | 638 | 1,070 |
| Totals ... ... ... | 7,765 | 11,425 |

# IRIDIUM, AND OTHER RARE METALS.

THE principal sources of iridium are two native alloys, known as Platiniridium and Osmiridium or Iridosmine.

Platiniridium usually occurs in angular grains, and rarely in cubical crystals. It is of a silver-white colour, with a tinge of yellow on the surface, and gray on fracture. Its hardness is from 6 to 7, and its specific gravity from 22·6 to 22·8. It consists of an alloy mainly of iridium and platinum, together with small quantities of other rare metals.

Osmiridium or iridosmine occurs in irregular flattened grains, and rarely in hexagonal crystals. Its colour is tin-white to light steel-gray, and it consists of an alloy of iridium and osmium in different proportions, together with some rhodium, platinum, and other allied metals. Its hardness is from 6 to 7, and its specific gravity varies from 19·3 to 21·1. Two varieties, depending on the proportion of iridium present, have been named Newjanskite and Sisserskite, respectively.

*Uses of Iridium.*—An alloy of pure platinum and pure iridium is used for the standards of weights and measures.

Iridium, in the condition of sponge and oxide, is used in photography and the ceramic art for obtaining a dense black, and by jewellers for obtaining black under a white or transparent enamel.

The principal use of iridium is making hard durable points for gold pens; for many years the native alloy known as iridosmine was employed for this purpose, but latterly the substance phospho-iridium has largely superseded it. According to Mr. Foley, of New York (*Mineral Industry*), the best iridium comes from Russia, and is worth from $10 to $40 per ounce. The crude material is separated into the different sizes required by sifting through brass sieves; finally, the best grains are picked out by hand, with the aid of a microscope, and these are worth from $100 to $200 per ounce.

Phospho-iridium is also used for pointing fine mechanical tools, and it is also said to be superior to steel for draw-plates in the manufacture of fine wire from gold, silver, copper, and iron. It has also been successfully employed for the knife-edges and bearings of very fine balances.

## *New South Wales Occurrences.*

The late Rev. W. B. Clarke was the first to refer to the occurrence of iridium in New South Wales. In his work "The Southern Goldfields" (page 271) he mentions the detection, in the alluvia of the northern and southern gold-fields, of small particles of a white mineral "some of which," he asserts, "are undoubtedly native iridium, the colour, gravity, hardness, crystallisation, lustre, &c., all agreeing with the known composition of that mineral." He adds, "hitherto these minerals have been found in no profitable quantities."

In November, 1864, Dr. A. Leibius, Assayer to the Sydney Mint, recorded* the occurrence of the metals osmium and iridium in the gold smelted in the Sydney Mint, and stated that, up to that date, three pounds weight of the metals had been collected.

In 1881 a specimen of a yellowish-red mineral was found near Emmaville, and was analysed by the late Mr. C. Watt, who identified it as monazite. The following is a copy of the analysis:—

| | |
|---|---|
| Phosphoric acid ... ... ... ... ... | 25·09 |
| Oxide of cerium ... ... ... ... ... | 36·64 |
| Oxide of lanthanum } Oxide of didymium } ... ... ... ... | 30·21 |
| Oxide of thorium ... ... ... ... ... | 1·23 |
| Oxide of manganese ... ... ... ... | traces |
| Magnesia ... ... ... ... ... ... | traces |
| Alumina ... ... .. ... ... ... | 3·11 |
| Silica ... ... ... ... ... ... ... | 3·21 |
| | 99·49 |

The mineral has never been found in quantity, although one or two small fragments have since been obtained from the same district.

In 1885, Mr. F. A. Genth described† the occurrence of iridosmine associated with native tin, cassiterite, native copper, gold, and platinum, in some sand from the Aberfoil River, New South Wales. He says, "The so-called iridosmine seems to be present both as Newjanskite, in tin-white flat scales, and as Sisserskite, in grayish-white or lead-coloured scales. Some of the scales are indistinct hexagonal plates, but mostly have an irregular shape."

Professor Liversidge states (Minerals of New South Wales) that he has observed iridosmine in fair quantities in the gem-sand at Bingara, Mudgee, Bathurst, and other places.

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* *Trans. Phil. Soc. N.S. Wales for* 1862-65, pp. 210-215.
† *Procs. Am. Phil. Soc.*, 1886, xxiii, p. 31.

# SILVER.

The principal ores from which silver is obtained in New South Wales are argentiferous galena, cerussite, zincblende, mispickel, iron pyrites, copper pyrites, and limonite (gossan) resulting from the decomposition of pyrites.

In the various argentiferous lodes the following minerals have been found in greater or less quantities :—

*Native Silver*; crystallises in the isometric system in cubes and octahedrons, also in masses, scales, and in arborescent and filiform shapes. Colour and streak silver white, tarnishing from gray to black; ductile and malleable; hardness 2·5—3; specific gravity 10·1—11·1.

*Dyscrasite*, antimonial silver; crystallises in the orthorhombic system, also massive, and as pseudomorphs after siderite (Australian Broken Hill Consols Mine); composition antimonide of silver, the proportions of the two metals varying considerably; thus the mineral has been found to contain from 73 to 94 per cent. of silver, and from 6 to 27 per cent. of antimony, agreeing with the following formulæ; $Ag_3$ Sb; $Ag_4$ Sb; $Ag_6$ Sb; $Ag_{12}$ Sb; $Ag_{18}$ Sb. Lustre metallic; colour and streak silver white, tarnishing to yellow or blackish; sectile; hardness 3·5—4; specific gravity 9·44—9·85.

*Cerargyrite*, or Horn Silver; composition silver chloride=chlorine 24·7, silver 75·3 per cent.; crystallises in the isometric system in cubes and octahedrons; frequently massive and as incrustations; resembles wax in appearance; easily sectile; lustre resinous to adamantine; colour pearl-gray, grayish-green, whitish to colourless; on exposure to light turns violet-brown; transparent to translucent; hardness 1—1·5; specific gravity 5·55.

*Bromyrite*; composition silver bromide=bromine 42·6, silver 57·4 per cent.; crystallises in the isometric system, but occurs usually in small concretions; sectile; lustre resinous to adamantine; colour bright yellow to amber yellow, sometimes greenish; transparent to translucent; hardness 2—3; specific gravity 5·8—6.

*Iodyrite*; composition silver iodide=iodine 54, silver 46 per cent.; crystallises in hexagonal prisms, also massive, and in thin flexible plates; sectile; lustre resinous to adamantine; colour citron and sulphur-yellow to yellowish-green, and sometimes brownish; streak yellow; translucent; soft; specific gravity 5·6—5·7.

*Embolite*; composition silver chloro-bromide, Ag (Cl, Br), the ratio of chlorine to bromine varying considerably; crystallises in the isometric system, also massive, stalactitic and concretionary; sectile; lustre resinous to adamantine; colour grayish-green and asparagus-green to yellowish-green, also yellow; becomes dark on exposure to light; transparent to translucent; hardness 1—1·5; specific gravity 5·31—5·43.

*Argentite*, silver glance; composition silver sulphide, $Ag_2 S$=sulphur 12·9, silver 87·1 per cent.; crystallises in the isometric system, also massive, and as incrustations; sectile; lustre metallic; colour and streak blackish lead-gray; opaque; hardness 2—2·5; specific gravity 7·2—7·36.

*Stephanite* or Brittle Silver Ore; composition silver sulphide and antimony sulphide, $Ag_5 SbS_4$=sulphur 16·3, antimony 15·2, silver 68·5 per cent.; crystallises in the orthorhombic system, also massive, compact, and disseminated; brittle; fracture sub-conchoidal to uneven; lustre metallic; colour and streak iron-black; opaque; hardness 2—2·5; specific gravity 6·2—6·3.

*Pyrargyrite*, Ruby Silver Ore; composition silver sulphide and antimony sulphide, $Ag_3 SbS_3$=sulphur 17·8, antimony 22·3, silver 59·9 per cent.; crystallises in the rhombohedral system, also massive and compact.; brittle; fracture conchoidal to uneven; lustre metallic-adamantine; transparent in thin splinters; colour black to grayish-black, but deep red by transmitted light; streak purplish red; hardness 2·5; specific gravity 5·77—5·86.

*Proustite*, Light Red Silver Ore; composition silver sulphide and arsenic sulphide $Ag_3 As S_3$=sulphur 19·4, arsenic 15·2, silver 65·4 per cent.; crystallises in the rhombohedral system, also massive and compact; brittle; fracture conchoidal to uneven; lustre adamantine; colour scarlet vermilion; streak ditto; transparent to translucent; hardness 2—2·5; specific gravity 5·57—5·64.

*Argentiferous Fahlerz*; composition variable, copper sulphide, with antimony sulphide or arsenic sulphide, and with some of the copper replaced by silver; crystallises in the isometric system in tetrahedrons, also massive, granular, and compact; rather brittle; fracture sub-conchoidal to uneven; lustre metallic, often splendent; colour between flint-gray and iron-black; streak ditto; opaque, sometimes sub-translucent in very thin splinters; hardness 3—4·5; specific gravity 4·4—5·1.

The silver-mining industry has of late years assumed such proportions that the value of the annual production of the white metal quite overshadows that of gold, and this notwithstanding the extremely low price of silver as compared with its value ten years ago.

## History of the Discovery of Silver in New South Wales.

So far as the records show, Count Strzelecki was the first to discover the presence of silver in the rocks of New South Wales. He mentioned this matter very clearly in two letters, extracts from which have been already quoted on page 2. The letters were dated October, 1839, and were addressed to Mr. Thomas Walker and Captain King, respectively. In a book published in 1845, and entitled "Physical Description of New South Wales and Van Diemen's Land," he also records a similar discovery (of native silver) at Piper's Flat.

The following extract is from the late Rev. W. B. Clarke's "Southern Gold-fields," published in 1860:—"Silver has been found in two or three instances in the same way (*i.e.*, in alluvial drifts), in arborescent crystals or small fragments. The crystals now mentioned belong to the southern districts, and have been found since 1852."

Since that date, silver, both native or free, and in a chemically combined state in galena and other ores, has been discovered in a great many localities in the Colony. The following is a list of the places where the principal deposits have been or are being worked:—

- Boorook, near Tenterfield.
- Borah Creek, near Inverell.
- Broken Hill, Barrier Ranges.
- Little Plant Creek (Webb's), near Emmaville.
- Moruya (Guy's Mine).
- Pye's Creek, near Deepwater.
- The Peaks, Burragorang.
- Rivertree.
- Rockvale, near Armidale.
- Sunny Corner, near Rydal.
- Wallah Wallah, near Burrowa.

*The Moruya Silver-mine.*—Although silver, both in the free state and in galena and other ores, was known to occur in numerous places in the Colony, many years elapsed before serious efforts were made to extract it. It was in the Moruya Mine that the first attempt was made to test the commercial value of our argentiferous deposits, and, unfortunately for the enterprise of the owners, the ore in this particular mine is of an extremely refractory character, consisting of arsenical pyrites (mispickel), zincblende, and galena, in a quartz gangue. At the time the mine was opened there were no facilities for treating an ore of that composition locally, and the Company, in the year 1864, shipped 120 tons of it to London, where it was sold to smelters. This ore is said to have contained an average of 22 ounces of silver and 1 ounce 8 dwt. of gold per ton. However, as the freight and London charges absorbed nearly the whole of the money realised by the sale, mining operations were suspended. Since then several unsuccessful attempts have been made to treat the ore, but at the present time it is being sent to the Wallaroo Smelting Works, in South Australia, and it is understood that satisfactory returns are being obtained from two classes of ore. According to Mr. Guy, the present owner of the mine, these ores have the following composition, viz.:—

No. 1 Ore.—Zinc, 17 per cent.
Lead, 26 ,,
Arsenic, 9½ ,,
Silver, 54 ounces per ton
Gold, 11 dwt. ,,

No. 2 Ore.—Silver, 10 ounces per ton
Gold, 4 oz. 2 dwt. per ton, with a high percentage of arsenic, but not much zinc or lead.

The lode is situated about four miles south of the town of Moruya, on the South Coast. It occurs in slate (probably of Upper Silurian age) near its junction with granite; it trends about N. 20° E., and dips in a westerly directly, while its width is very irregular, varying from three inches to three feet. The zincblende and galena carry most of the silver, and the bulk of the gold is contained in the arsenical pyrites ; it seems probable that the ore can be satisfactorily treated on suitable concentrating machinery, and there is every reason to hope that this mine will have a successful future.

*Discovery of Argentiferous Lead Ore at Thackeringa.*—In the year 1876, Mr. P. Green, of Wilcannia, discovered a lode of silver lead ore at Thackeringa, about twenty miles south-west of the present town of Broken Hill, and took up forty acres of land as a Mineral Conditional Purchase, for the purpose of working the lode. He extracted thirty-six tons of the ore, which he shipped to England for treatment. The ore was jettisoned on the voyage, and nothing further was done with the lode until 1880, when Green shipped another parcel of one hundred tons to England, and after an interval of two years he received a report to the effect that the ore was of considerable value, and that it contained about thirty-five ounces of silver per ton, and sixty per cent. of lead. As a consequence of this a rush occurred in this locality in the year 1882, when several Mineral Conditional Purchases, and a large number of Mineral Leases, were applied for. None of these mines were of permanent richness, though considerable yields of silver were for a time obtained from some of them ; they led to further prospecting, however, and to the discovery in the following year of the celebrated Broken Hill Lode, which will be referred to later.

*The Boorook Silver Mines.*—In the year 1878 it was discovered that some lodes, at Boorook, which had originally been taken up for gold, contained, in addition, considerable quantities of silver. The Boorook field is situated about twenty-six miles north-east of Tenterfield. The lodes occur in rocks of Carboniferous age, consisting of claystones and tuffs, intersected by dykes of felspar porphyry. The strike of the lodes is about N. 25° E., and their dip is westerly. The gangue or matrix consists of quartz, and disseminated through this were found the silver-bearing minerals, consisting of chloride of silver (Cerargyrite), sulphide of silver (Argentite), ruby silver ore (Pyrargyrite), argentiferous pyrites, and native silver, with which were associated galena, zincblende, chlorite, and free gold. Hand samples of the ore yielded by assay from 1 to 522 ounces of silver per ton. In the oxidised portion of the lode the silver occurred chiefly as chloride, and the treatment adopted consisted in crushing the ore in a stamper battery, and then grinding it, in a Wheeler's pan, with mercury ; the resulting amalgam was then retorted. A very considerable proportion of the silver was lost by this method of treatment. Below the water-level, which was met with about seventy-five feet from the surface, and from that depth to one hundred and forty feet, the greater part of the silver was contained in pyrites and zincblende, while below one hundred and forty feet the prevailing minerals were native silver and argentite.

Only three mines in this field were worked to any depth, viz., The Golden Age, Addison's, and the Silver King, and these three adjoined

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one another. The main lode has a strike of N. 29° E., and its dip is north-westerly. It was intersected and heaved by a cross-course, bearing north and south, and consisting mostly of clay, with a little quartz in detached pieces, which, near the junction with the main lode, were rich in silver. The richest deposits of silver ores were found in the main lode near its junction with the cross-course, while the lode gradually became poorer at a distance from the latter. The main lode averaged four feet in width in the Golden Age Mine, though in one place it attained a width of nineteen feet. For a considerable depth it contained from 60 to 350 ounces of silver to the ton, but at a depth of 280 feet the country changed to syenite, and the lode then became poorer. After the workings had reached a depth of 300 feet mining operations were ceased, as the ore was found to be too poor to pay for extraction.

Complete returns of the silver and gold from this field are not available; but the following statement is compiled from the Annual Reports of the Department of Mines:—

| Year. | Silver. | Gold. | Value. |
|---|---|---|---|
| | oz. | oz. | £ |
| 1879 ... ... ... | 25,416 | ........ | 5,520 |
| 1880 ... ... ... | 31,725 | ........ | 6,443 |
| 1881 ... ... ... | 5,814 | ........ | 1,163 |
| 1883 ... ... ... | 15,792 | 682 | 6,241 |
| 1884 ... ... | 34,000 | 738 | ........ |

*The Sunny Corner Silver Mines.*—The Sunny Corner Lode was originally worked for gold; it was taken up for this purpese in 1875 by Messrs. Winters and Morgan, who are understood to have made a very considerable sum of money out of the auriferous deposits. In the year 1886 it was taken up by the Sunny Corner Silver-mining Company, of 64,000 shares, on which only one shilling per share was called up. This Company in ten years paid £100,000 in dividends, when, the ore becoming poorer, the mine was let on tribute, and, ultimately, the tributors obtained the ownership of the mine. Sunny Corner is situated about fifteen miles north-west of Rydal, on the western railway line. The country consists of claystones and sandstones, probably of Silurian age, with dykes of hard felsite and felspar porphyry. The felsites and felspar porphyries are highly charged with small crystals of iron pyrites, copper pyrites, arsenical pyrites, galena, and zincblende. The general trend of the felsite dykes is north and south; but occasionally they make sudden bends at right angles to that course. There is no regular lode, but the deposits take the form of bunches of ore, which occur along the line of contact between the felsite and the sedimentary rocks, more particularly in the elbows formed by the sudden change in direction of the dykes. Some of the bunches of ore have been as much as three hundred feet long and forty feet wide. The general dip of the ore-bunches is westward. The footwall of the deposits consists of felsite of a peculiar spheroidal character; the spheroids are sometimes several feet in diameter, and are known locally as "boulders." They are regarded as indicators of the presence of ore bodies. From the occurrence of metallic sulphides, disseminated through the felsite, it appears probable that the ore-bunches were derived from this source.

The cap of the lode consists of porous gold-bearing quartz, and argentiferous gossan, containing both native silver (in arborescent forms) and chlorobromide (embolite); below that a dense ore consisting of undecomposed mixed sulphides of iron, copper, lead, and zinc with mispickel was obtained.

These sulphides contained a variable proportion of lead, silver, copper, and gold. In some places as much as seventy ounces of silver per ton was obtained; but as deeper levels were reached the ore was of a decidedly low grade.

Messrs. Winters and Morgan, who successfully worked the upper portion of the principal ore body for gold, left several thousand tons of tailings containing nearly half an ounce of gold, and thirty ounces of silver per ton. These tailings were subsequently mixed with sulphide ores, and smelted by the Sunny Corner Silver-mining Company with highly profitable results.

*Metallurgical treatment of the Ore.*—This Company smelted ore in waterjacket furnaces, and at first there was considerable loss of silver in the slags, and the cost of furnacing was very high, owing to the want of knowledge of this class of work, which was new to Australia. Subsequently, however, as experience was gained, the total cost of treating the ore was reduced to a very low figure, and the percentage of metals extracted was highly satisfactory. Finally the fall in the price of silver and the reduced quality of the ore obtained in the deeper levels caused the Company to go into liquidation. A new Company was formed but succeeded no better, and the mine was then let on a five per cent. tribute with the option of purchase. The tributors succeeded for some time in treating the ore profitably by smelting, and accordingly purchased the mine; but eventually had to cease work owing to the extremely low price of silver.

The principal mines on this deposit were the Sunny Corner, the Nevada, the Silver King, Tonkin's, the Cornstalk, and the Silver Hill, but of these only the Sunny Corner was proved to contain what might be termed permanent ore-bodies.

*Discovery of the Broken Hill Lode.**—The rush to the silver-lead deposits of Thackeringa, which occurred in the year 1882, was followed by another rush to Silverton and the Appolyon Valley. This led to the

* An interesting memoir on the geology of the Broken Hill Lode and Barrier Ranges Mineral Field, by Mr. J. B. Jaquet, Geological Surveyor, was published in 1894.

*Photographed by E. F. Pittman.*

BROKEN HILL SILVER LODE.

The Open Cut—looking south towards Block 10. Depth of cut, 200 feet.

survey and proclamation of the town of Silverton in 1883, and before the end of the year it had a population of five hundred, while an area of 5,180 acres had been taken up in mineral leases. The excitement was increased by the finding, on the surface, of a considerable number of solid masses of chlorobromide of silver (embolite), locally termed "slugs." These slugs were derived from the denudation of the upper portions of silver-bearing lodes, and some of them contained over fifty-five per cent. of silver. One of the slugs was purchased for the Geological Museum. It weighed 32 lb. 11 oz., and an analysis of a portion of it by Mr. J. C. H. Mingaye, Analyst to the Department of Mines, gave the following results:—

| | |
|---|---|
| Moisture ... ... ... ... ... ... | ·50 |
| Oxide of lead ... ... ... ... ... | 30·60 |
| Oxide of iron ... ... ... ... ... | 8·71 |
| Silver... ... ... ... ... ... ... | 33·90* |
| Silica... ... ... ... ... ... ... | 3·15 |
| Alumina ... ... ... ... ... ... | 2·59 |
| Lime ... ... ... ... ... ... ... | ·40 |
| Magnesia ... ... ... ... ... ... | ·43 |
| Bromine ... ... ... ... ... ... | 5·92 |
| Chlorine ... ... ... ... ... ... | 7·33 |
| Sulphur ... ... ... ... ... ... | ·38 |
| Phosphoric acid ($P_2O_5$) .. ... ... ... | ·92 |
| Carbonic acid ($CO_2$) ... ... ... ... | 5·00 |
| Minute trace of gold, trace of copper, loss, &c.... | ·17 |
| | 100·00 |

Prospecting operations revealed the presence of lodes in the neighbourhood of the slugs, and enormously rich parcels of ore were obtained from some of them. It was subsequently found, however, that the lodes were of small dimensions, and that the rich ore did not extend to any depth. There was no regular production of silver ore from this field, except in the case of the Day Dream, and two or three other mines. At the Pinnacles, Thackeringa, and Umberumberka Mines, however, the lodes were of a more permanent character, though the ore was of a lower grade. Prospecting in this country was a matter of great difficulty, by reason of the scarcity of water. The district was practically a desert, consisting chiefly of sterile plains, covered with sombre-looking mulga scrub and salt-bush herbage, and only relieved by a few isolated conical hills and low, rocky ranges. The average annual rainfall is under 10 inches, and during the year 1888 only 3·26 inches of rain were recorded.

*The Great Broken Hill Lode* was taken up by a local man of no experience in mining matters, and there can be no doubt that his interest in mineral deposits was stimulated, if not entirely caused, by the amount of prospecting which had already been done in the District, and by the fabulously rich assay values of some of the ores discovered. The story

* = 11,074 oz. of silver per on.

of the pegging-out of this wonderful mine is given in the words of the late Mr. Wyman Brown, Warden and Police Magistrate of the District: —"In September, 1883, one Charles Rasp, who was then a boundary-rider on Mount Gipps Station, marked out an area of forty acres, believing the enormous outcrop of manganese to be tin. On reaching the station at night he informed Mr. McCulloch, the General Manager of the station, also his mates, of what he had done, when it was then and there determined to form a small syndicate, consisting of seven persons, all station hands, each putting £70 into the venture. The first thing done was to apply for a mineral lease of the land taken up by Rasp, together with six other forty-acre blocks on the same line. These seven blocks now constitute the Broken Hill proper, and were originally applied for by the following persons:—George McCulloch, George Urquhart, Charles Rasp, James Poole, Philip Charley, David James, and George M. Lind. Work was soon commenced, and assays made for tin; but, I need hardly say, with no beneficial results. It was then decided to sink a shaft and prospect for silver, which, by this time, had been proved to exist in the district. The country being hard, and the sinking not showing very encouraging prospects, coupled with the fact that the small amount of capital that had been subscribed had been exhausted, caused some of the original shareholders to sell to others, Lind being the first to retire, his interest being taken by McCulloch and Rasp, Urquhart being the next to give in. It was now determined to increase the syndicate to fourteen, for the purpose of raising more funds for further prospecting. This arrangement was carried out, and the work continued until the latter part of 1884, when chlorides were first found in Rasp's shaft, at a depth of about one hundred feet. Shortly after rich chloride ore was found in the cap of the lode, at a different part of the mine."

The sinking of Rasp's shaft was proceeded with for a time, but the results were discouraging. The site for the shaft happened to have been selected on one of the poorest portions of the lode, and the ore, for a considerable time, only yielded about ten or twelve ounces of silver per ton. The shares were at a discount, and there were many offers to sell them at prices which, in the light of subsequent developments, appear ridiculous. One gentleman bought three 14th shares for £330; for the first of these he paid £100, and for the other two £110 each. He sold one of the shares for what it cost him, and another for £200, retaining the third share. About a year later this share was worth £30,000, and within six years its market value, with dividends and bonuses added, was about £1,250,000. But the cheapest sale of all was that of two of the original $\frac{1}{7}$th shares, which were disposed of for less than £100 each, and which were afterwards worth £2,500,000 each.

Towards the end of 1884 an enhancement in the value of the shares took place, consequent upon the discovery of rich chloride ore at the bottom of Rasp's shaft, and also in the outcrop of the lode to the south of the shaft. Further important discoveries, in the shape of rich ore,

*Photographed by E. F. Pittman.*

BROKEN HILL SILVER LODE.

The Open Cut—looking south from Block 13. Depth of cut, 200 feet.

followed, and the Broken Hill Silver Mines soon overshadowed all the other mines on the field, although the output of the former for 1884 was only 3,000 tons valued at £42,866, as against 4,000 tons valued at £54,000, extracted from the Day-Dream Mine.

*Formation of the Company.*—On the 10th August, 1885, the Broken Hill Proprietary Silver-mining Company was floated, with 16,000 shares of £20 each; the fourteen shareholders received 1,000 shares each, paid up to £19. The remaining 2,000 shares were offered to the public at £9 per share on allotment, such shares to be then considered as paid up to £19, after which all shares alike were liable to a call of £1 on the formation of the company. The original proprietors were paid £3,000, in addition to their 14,000 shares, for expenses previously incurred. The company therefore started with a working capital of only £15,000.

Mining operations were immediately commenced on an extensive scale, and water-jacket furnaces were erected for smelting the ore. The preliminary workings, consisting of shafts and drives, were all excavated through rich ore, so that there was really no "dead work." Only one call was ever made, viz., in 1889, and the gross profits from the mine for the first six months were £89,912. On the 31st January, 1889, the number of shares was increased from 16,000 to 160,000 by dividing each £20 share into ten shares of the nominal value of £2, these being issued as paid up to £1 18s., and towards the end of the same year a call of two shillings per share was made.

In February, 1890, the number of shares was increased from 160,000 to 800,000, while their nominal value was correspondingly reduced from £2 to 8s. New shares to the number of 160,000 were also issued, making the total number of shares in the company 960,000.

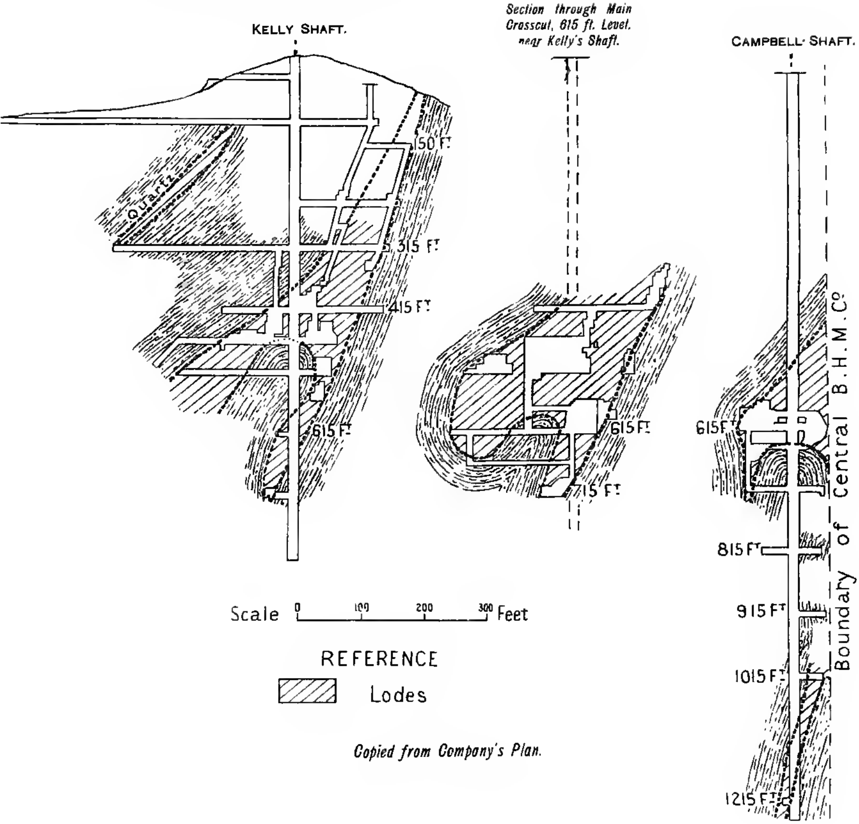
It has already been stated that the property originally consisted of seven 40-acre blocks. These were known as Blocks 10, 11, 12, 13, 14, 15, and 16.

In 1887 Block 14 was sold to a company named the Broken Hill Proprietary Block 14 Silver-mining Company. This new company's capital was £500,000, distributed among 100,000 shares, which were issued as paid up to £4 10s. Of these, 96,000 shares were divided *pro rata* among the shareholders of the parent company, the proceeds of the remaining 4,000 forming the working capital of the new company. Towards the end of the same year Blocks 15 and 16 were sold to the British Broken Hill Proprietary Company. The authorised capital of this company was £1,320,000, and the subscribed capital £1,200,000. The shareholders in the parent company received, in payment for the two blocks, shares to the value of £400,000 and the sum of £576,000 in cash.

In March, 1888, Block 10 was sold to the Broken Hill Proprietary Block 10 Company, whose capital was £1,000,000 in 100,000 shares of £10 each. The shareholders in the parent company divided 96,000 shares in payment for the block, and the proceeds of the sale of the remaining 4,000 shares formed the working capital of the new company.

BROKEN HILL BLOCK 10 CO., LTD.

Transverse Sections looking North-east.




Copied from Company's Plan.

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Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

the normal outline of a saddle lode, yet this is not the case everywhere for occasionally one leg may be suppressed, or only appear in a rudimentary form; irregularities, in fact, occur in places, but in such cases there will be found to be corresponding irregularities in the bounding rocks, so that the apparent anomalies do not, in any way, refute the theory that the deposit has filled a cavity, caused by the contorting of two contiguous beds. The cap of the lode follows an undulating line in longitudinal section, being considerably higher in some mines than in others. The walls of the lode are not very well defined, and the adjoining country rock is often ore-bearing for some distance owing to metasomatic action, or replacement. The outcrop of the lode, which has now been nearly all removed in an open cut, varied in width from twenty to one hundred feet. It was composed of massive manganiferous limonite, associated with some siliceous and aluminous material. Numerous vughs occurred in it, and these contained crystals of carbonate of lead (cerussite), chloride, iodide, and chloro-bromide of silver, and stalactites of oxide of manganese (psilomelane). The iron-ore also contained from two to thirty ounces of silver per ton, and from ten to twenty-five per cent. of lead. It was therefore used as a flux for the siliceous ores which were found below it. Underneath the ironstone outcrop, and between it and the sulphide ores, vast quantities of so-called oxidised ores occurred. These were locally known as (1) carbonate ore, (2) dry high-grade ore, and (3) dry low-grade ore.

(1.) The carbonate ore consisted of a loose aggregation of crystals of carbonate of lead, and a gangue composed of siliceous and aluminous material, impregnated, more or less, with manganiferous iron oxide. The silver in this ore occurred chiefly as chlorobromide and native silver, but a small proportion of iodide and chloride of silver was always present. This ore contained from five to eighty ounces of silver per ton, and from twenty to sixty per cent. of lead.

(2.) The dry high-grade ore consisted chiefly of kaolin, with some garnets and quartz, with native silver, frequently in large scales or plates, and also chloride, chlorobromide, and iodide of silver. It was worth from four to three hundred ounces of silver per ton, and contained three per cent. of lead.

(3.) The dry low-grade ore only differed from the carbonate ore in containing a much smaller quantity of cerussite, with a larger proportion of gangue. It yielded from five to forty ounces of silver per ton.

Below the oxidised zone the lode was found to consist of massive sulphide ore. This consisted of an intimate mixture of rather fine-grained argentiferous galena and zincblende, with a certain amount of quartz, garnet, rhodonite, and felspar, iron and copper pyrites, and sometimes small quantities of mispickel, wulfenite, and fluorspar. The sulphide ore, as a rule, has a compact granular structure, and so intimately are the two chief constituents intermixed that it is often impossible to distinguish the zincblende from the galena. The silver occurs partly in one mineral and partly in the other. The sulphide ore contains from five to thirty-six ounces of silver and two or three pennyweights of gold per ton, from five to fifty per cent. of lead, and from fourteen to thirty per cent. of zinc.

A complete analysis of a sample of this ore from Block 10 Mine was made by Mr. J. C. H. Mingaye, F.C.S., and the result was as follows:—

| | |
|---|---|
| Moisture | 2·065 |
| Iron | 5·675 |
| Lead | 18·755 |
| Zinc | 28·251 |
| Copper | ·244 |
| Arsenic | ·057 |
| Antimony | trace |
| Cadmium | strong trace |
| Bismuth | nil |
| Silver | ·0925 |
| Gold | trace |
| Alumina | 2·161 |
| Lime (CaO) | nil |
| Magnesia (MgO) | 2·399 |
| Sulphur | 20·426 |
| Carbonic acid | ·350 |
| Gangue (garnets, sand, and fine clay) | 18·500 |
| Soluble salts | ·510 |
| | 99·4855 |

It has been already stated that the Broken Hill lode belongs to the type of bedded deposit known as a "saddle lode," because of its resemblance, in cross section, to the section of a saddle. The widest part of such a lode occurs, as a rule, just about where the deposit forks, or divides into two legs (which correspond with the flaps of the saddle); and it follows, from the mode of formation of the cavity in which the deposit is found, that the two legs must gradually become narrower as they are traced downwards. So far as is known, the Broken Hill lode is the largest example of this class of deposit which has hitherto been worked. In the widest part of the oxidised zone it contained payable ore for nearly three hundred feet in width, and at the present time the lode is being worked for a width of about four hundred and fifty feet (consisting of solid sulphide ore) across the boundary common to Block 10 and the Central Mine.

Considerable difficulty was found in supporting excavations of such enormous dimensions, more especially in the upper levels, where much of the material, such as the carbonate ore, was of a very loose or incoherent nature; but advantage was soon taken of the experience gained under somewhat similar conditions in the Great Comstock Lode of Nevada, United States, and the method of timbering used there, and known as the "square set" system, was adopted. The best Oregon pine timber, in the form of squared logs, was imported from Puget Sound for the purpose. Where the method was faithfully carried out,

*Photographed by E. F. Pittman.*

OUTCROP OF THE BROKEN HILL SILVER LODE.

As seen from the Open Cut, looking towards Block 14.

and was supplemented by the filling in of a certain proportion of the sets with rubble stone, as in Black 10, the results were very satisfactory ; there were, however, several disastrous subsidences, which were traceable to neglect of the proper precautions in this respect, and, in addition to this, it became evident that the square-set method was very expensive, more especially in the deeper levels where greater pressure had to be withstood, and where the ore was of lower value. The idea was then conceived of removing the whole of the upper portion of the lode by means of an open cut, and for some years past this work has been proceeding in the Broken Hill Proprietary Mine. The cut has already reached a depth of over two hundred feet, and it is understood that an attempt will be made to carry it down to a total depth of two hundred and fifty feet. The method has been very successful, for not only has it enabled the Company to extract, at a reasonable cost, a quantity of ore which, owing to subsidence, etc., could not otherwise have been reached, but it has also facilitated the recovery of a large quantity of valuable timber which can be used over again ; and, in addition to this, it has removed a great proportion of the pressure which the lower levels had previously to withstand.

The depth to which the open cut can be carried on is, however, limited by the necessity for continually increasing its width, so as to provide the batter, or angle of slope, that will enable the sides of the excavation to stand, and this limit is, of course, governed by the cost of the work.

*Minerals occurring in the Lode.*—The Broken Hill lode formed a veritable treasure-house for the enthusiastic mineralogist, for not only did it contain a great number of varieties of minerals, but some of the specimens of the rarer minerals were unique as regards their size and beauty. Three minerals new to science were discovered, viz., Marshite (iodide of copper), Willyamite (sulph-antimonide of cobalt and nickel), and Raspite (a new form of tungstate of lead).

List of Minerals found in the Broken Hill and "Consols" Lodes.

Atlasite.
Argentite.
(Antimonial silver chloride).
Aurichalcite.
Azurite.
Bindheimite.
Boulangerite.
Bournonite.
Brongniardite.
Bromyrite.
Calcite.
Calamine.
Calomel.
Cerargyrite.
Cerussite.
Chalcotrichite.
Chalybite.
Chromo-pyromorphite.
Cuprite.
Chrysocolla.
Cobaltite.
Dyscrasite.
Embolite.
Erinite.
Fahlerz.
Fluor Spar.
Galena.
Garnet.
Hedyphane.
Hydrozincite.
Iodyrite.
Jalpaite.
Jordonite.
Kampylite.
Lanarkite.
Limonite.
Linarite.
Malachite.
Marshite.
Matlockite.
Mimetite.
Mispickel.
Onofrite.
Percylite
Phosgenite.
Pilarite.
Polybasite.
Proustite.
Psilomelane.
Pyrargyrite.
Pyromorphite
Raspite.
Rhodonite
Sartorite.
Stephanite.
Stibnite.
Stolzite.
Stromeyrite.
Volgerite.
Willyamite.
Wulfenite.
Zincblende.

*Treatment of the Ore.*—The metallurgical treatment of the oxidised ores of Broken Hill presented no difficulties; the kaolin and carbonate ores were mixed and smelted with ironstone and limestone fluxes and coke in water-jacket furnaces, and the resulting lead bullion was either shipped to England or (latterly) refined at Port Pirie. Large quantities of the richer sulphides have also been smelted at Broken Hill, with the sacrifice of the zinc contents, and the lower grades have been concentrated with fairly good results. Recently the smelting furnaces have been removed to Port Pirie. The chief difficulty, however, in dealing with these ores has been to find a process which would enable the zinc to be recovered. Nearly all the oxidised ore-bodies have now been exhausted, and in view of the great depreciation in the price of silver, it has for some time been evident that, in order to make the treatment of the low-grade sulphide ores (which now form the bulk of the deposits) an economical success, the recovery of the zinc, as well as the lead and silver, is necessary. Several processes, having this object in view, have been tried, but have not proved payable. At the present time, however, there appear to be very good reasons for believing that the problem will be solved by the use of Wetherill Separators.

It may be repeated that the sulphide ores at Broken Hill consist of an intimate mixture of zincblende and galena, together with rhodonite (silicate of manganese) and garnet (spessartite) and some quartz. In the concentrating plant the galena, containing some of the silver, is separated, with comparative ease, from the zincblende (carrying the balance of the silver), rhodonite, garnet, and quartz; but the specific gravities of rhodonite, garnet, and zincblende are so nearly alike that it is impossible to separate them from one another by purely mechanical means.

The process which is being adopted at Broken Hill consists in passing the finely-divided tailings (after separation of the galena) on travelling bands under the poles of an electro-magnet. The first effect of this is to attract the rhodonite and garnet, which are thus separated from the other ingredients; and on subsequently conveying the latter past a second and more powerful electro-magnet the zincblende is in turn attracted and separated. It may be mentioned that the zincblende of Broken Hill contains a notable proportion of sulphides of iron and manganese, which probably accounts for its attraction by the electro-magnet.

By the use of magnetic separators, therefore, in conjunction with ordinary concentrating machinery, two valuable products (argentiferous zincblende and argentiferous galena), containing practically the whole of the silver, lead, and zinc, are obtained from the low-grade sulphide ores at a comparatively low cost, and as the ore-bodies developed by recent workings are of enormous extent, there appears to be little doubt that the Broken Hill mines will enjoy a long period of renewed prosperity.

At a depth of 600–700 feet the lode, at the boundary between the Central Mine and Block 10, has been proved for a width of over 450 feet of solid sulphide ore, all of which is being sent to the mill.

In the Central Mine the average assay value of this ore for a width of 260 feet (in 1899) was as follows :—

Lead = 18·20 per cent.
Zinc = 22·24 ,,
Silver = 12–13 ounces per ton.

Mining, during the same period, cost about 10/6 per ton, including management, development, timbering, &c., while milling and concentrating cost about 4/- per ton of ore; the total cost (exclusive o treatment by magnetic separators, which had not then been started) was therefore 14/6 per ton, leaving a profit of about 14/- per ton of ore. In addition to this, it is anticipated that the zincblende (and its contained silver), which has hitherto gone into the tailings heap, will, under the magnetic separator treatment, return a profit of about 14/- per ton of ore.

In Block 10 mine enormous bodies of similar order are visible. The quality of this ore is shown by the following statement of the assays of crude ore and concentrates for the week ending 31 May, 1899 :—

| | Ton. | Silver—oz. per ton. | Lead—per cent. | Zinc—per cent. |
|---|---|---|---|---|
| Crude ore sent to mill ... ... | 3,215 | 15·64 | 18·6 | 22·59 |
| Jig and vanner concentrates ... | $525\frac{3}{8}$ | 34·56 | 64·9 | 7·6 |
| Jig tailings ... ... ... ... | ... ..... | 9·6 | 5·5 | 22·7 |
| Vanner tailings ... ... ... | ......... | 8·9 | 2·6 | 22·7 |

*Broken Hill Proprietary Crushing and Concentrating Plant.*—The big mine is now furnished with a very complete crushing and concentrating plant capable of treating from 9,000 to 10,000 tons of ore per week. The ore goes first through Gates crushers, and thence to bins, automatic feeders, and Blake crushers; it is then fed automatically into Cornish rolls, and from these it passes through trommels of $\frac{3}{32}$-inch mesh, the coarser material from the trommels being again crushed between fine rolls. The fines from the trommels are put through the hydraulic classifier, and pass thence to improved May jigs; the tails from these jigs are sent to the dump. The jiggings from compartments

3, 4, and 5 are ground in Heberle grinders, and are then raised by elevators to a fine trommel ($\frac{1}{20}$-inch mesh), the outfall of this trommel being reground in a Heberle grinder and hoisted to the same trommel. The fines from this trommel are treated on fine or slime-jigs. All hydraulic classifier overflows and slimes are raised by three double-acting 10-inch pumps into three distinct Spitzkasten, each 180 feet in length. These classifiers divide the slimes into thickened pulp and clear water, the pulp passing to Lührig and Wilfley vanners, and the clarified water being used to spray the same. The concentrates and tailings from the vanners flow direct to the loading bins and slime dump by gravitation, the same system of settling being adopted. There are two sets of vanners, upper and lower, the middles from the upper vanners being retreated on the lower ones.

The recovery by this plant is said to be always over 70 per cent. of the lead and about 43 or 44 per cent. of the silver contents, the greater part of the balance being in the zincblende in the tailings. Here again, therefore, the use of the magnetic separators will result in the saving of a valuable asset which was formerly lost.

The following figures show the composition of the sulphide ore, concentrates, and tailings from the Broken Hill Proprietary Mine in May, 1899 :—

| | Zinc—per cent. | Lead—per cent. | Silver—oz. per ton. |
|---|---|---|---|
| Crude sulphide ore... ... .. | 17 | 21 | 14 |
| Coarse concentrates ... ... | 9 | 58 | 22·5 |
| Fine concentrates ... ... ... | 11 | 46 | 20 |
| Zinc concentrates ... ... ... | 33 | 11 | 9–10 |
| Coarse tailings ... ... ... | 14 | 5·5 | 6 |
| Slime tailings ... ... ... | 16 | 16 | 12 |

*Phenomenal Returns of the Broken Hill Proprietary Company.*—Since its formation in August, 1885, up to the 30th November, 1899, the Broken Hill Proprietary Company has produced 403,624 tons of lead, 4,250 tons of copper, 101,061,080 ounces of silver, and 46,127 ounces of gold. It has, during the same period (13½ years), distributed amongst its shareholders, in dividends and bonuses, no less a sum than £9,168,000 ; and, on the basis of the present market price of its shares, the mine is still worth over two and a quarter millions sterling.

*Photographed by E. F. Pittman.*

THE BROKEN HILL PROPRIETARY SILVER MINE.

Annual Yield of Silver and Gold from the Broken Hill Proprietary Mine from 1885 to 1899 inclusive.

| Year. | Tons. | Silver—in ounces. | Gold—in ounces. | Lead—in tons. | Copper—in tons. |
|---|---|---|---|---|---|
| 1885 | 48 | 35,605 | ......... | ......... | ......... |
| 1886 | 11,500 | 1,016,269 | ......... | 1,991 | ......... |
| 1887 | 47,211 | 2,103,225 | ......... | 9,348 | ......... |
| 1888 | 94,125 | 3,924,192 | ......... | 16,659 | ......... |
| 1889 | 157,184 | 6,003,299 | ......... | 25,076 | ......... |
| 1890 | 207,311 | 7,727,877 | 643 | 30,339 | ......... |
| 1891 | 286,118 | 9,947,038 | 805 | 41,688 | 107 |
| 1892 | 254,825 | 8,065,148 | 1,826 | 36,497 | 173 |
| 1893 | 490,510 | 12,505,426 | 3,280 | 47,343 | 859 |
| 1894 | 595,194 | 14,054,393 | 4,080 | 49,595 | 775 |
| 1895 | 522,882 | 10,392,271 | 5,202 | 33,071 | 689 |
| 1896 | 426,325 | 8,135,870 | 6,321 | 22,023 | 493 |
| 1897 | 387,814 | 6,864,540 | 5,001 | 23,347 | 497 |
| 1898 | 419,165 | 5,565,230 | 14,841 | 30,993 | 450 |
| 1899 | 267,716 | 4,720,697 | 4,128 | 35,654 | 207 |
| Totals | 4,167,928 | 101,061,080 | 46,127 | 403,624 | 4,250 |

The principal mines on the Broken Hill Lode, to the south of the Proprietary Mine, are Block 10, the Central, and the Broken Hill South, while to the north of the big mine are situated Block 14, the British, the Broken Hill North, the Junction, and the Junction North.

The following are the principal shafts on the mines at Broken Hill, with their depth, in June, 1899:—

| | |
|---|---|
| Broken Hill South Mine,— | |
| Block 7 shaft... ... ... ... | 700 feet. |
| Block 8 ,, ... ... ... ... | 800 ,, |
| Broken Hill Central Mine,— | |
| Kintore shaft... ... ... ... | 650 ,, |
| Main ,, ... ... ... ... | 650 ,, |
| Broken Hill Block 10 Mine,— | |
| Campbell's shaft ... ... ... | 1,233 ,, |
| Kelly's ,, ... ... ... | 815 ,, |
| Broken Hill Proprietary Mine,— | |
| McBride's shaft ... ... ... | 1,050 ,, |
| Patterson's ,, ... ... ... | 700 ,, |
| Stewart's ,, ... ... ... | 500 ,, |
| Dickenson's ,, ... ... ... | 500 ,, |
| Broken Hill Block 14 Mine,— | |
| Main shaft ... ... ... ... | 580 ,, |
| British Broken Hill Mine,— | |
| Main shaft ... ... ... ... | 400 ,, |
| Broken Hill Junction Mine,— | |
| Brown's shaft... ... ... ... | 700 ,, |
| McIntyre's ,, ... ... . | 750 ,, |
| Junction North Mine, main shaft ... ... | 860 ,, |
| Broken Hill North Mine, main shaft ... | 700 ,, |
| *Broken Hill Extended shaft ... ... ... | 1,330 ,, |

* This shaft has been abandoned. A drive which was put in to the east from the bottom of it cut what was supposed to be the western leg of the Broken Hill lode, but it was only six feet wide, and of very low grade.

*Boom in Silver-mining Shares.*—The phenomenal richness of the Broken Hill silver lodes caused quite a feverish activity amongst mining men, and prospecting operations, in search of the white metal, were commenced all over the Colony. The result was a boom in silver-mining shares, which may be said to have commenced about the month of September, 1887, and which collapsed in June, 1888. During the period referred to the principal topic of conversation in the city was "silver," and people thought of little else than "indications of chlorides," "carbonate ore," &c.; wherever an outcrop of *gossan* was found, the surrounding land was pegged out for miles. Shoals of, so-called, mining experts sprang into existence as if by magic; the most optimistic reports were published, and companies were formed to work deposits, which, in many cases, did not exist, or were altogether overrated. Large fortunes were made—"on paper"—which, in a majority of instances, were never realised, because, on the collapse of the boom, the shares were valueless. Still, as an outcome of all this excitement, a number of argentiferous deposits were found, some of which will, doubtless, be worked, under more favourable circumstances, in the future.

*The Australian Broken Hill Consols Lode.*—This lode is situated about thirty chains east from the Broken Hill Lode, from which it differs in many essential points. The Consols deposit is a true fissure lode, varying in width from an inch to four feet, the average being about eighteen inches. Its strike is east and west, and its dip is towards the south at very variable angles; at the surface its inclination is about 25°; at a depth of three hundred feet the lode is nearly horizontal, while in the lower levels it is nearly vertical. In its course it cuts across beds of micaceous schist, gneiss, quartzite, and an intrusive hornblendic rock (amphibolite). Much of the silver in this deposit occurs in combination with antimony, in the form of the mineral dyscrasite, and this is generally found in "slugs" or masses, in the ore channel, at or near its intersection with cross-courses. One of these masses of antimonial silver weighed 16 cwt., and contained 83·5 per cent. of silver; it was valued at £3,520, at the then ruling price of the metal. Another slug weighed 6 cwt. 2 qrs. 21 lb., and contained 84 per cent. of silver. A fine specimen of dyscrasite, weighing 140·95 ounces, from the Australian Broken Hill Consols mine, was purchased for the Geological Museum collection. It is in the form of pseudomorphs after large crystals of chalybite. A great variety of other rare minerals are found in this mine, but these have already been enumerated in the list given above. The gangue, in which the valuable minerals occur, consists of chalybite, or carbonate of iron, with occasional patches of calcite, and more rarely quartz. In the upper levels the chalybite has been converted into limonite. The lode frequently exhibits comby structure, and its walls are well defined.

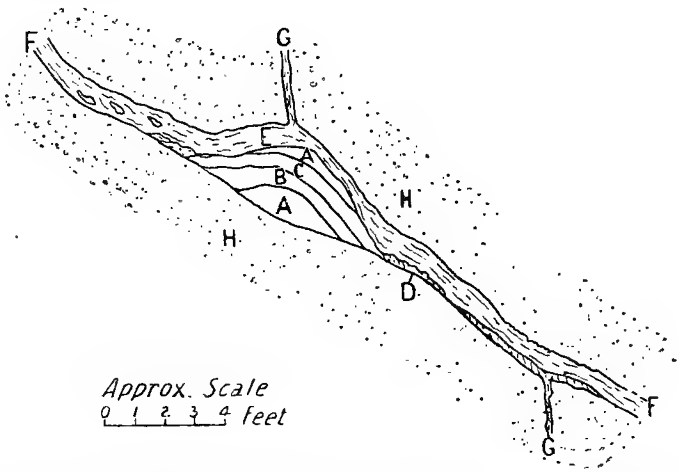
Fine masses of dyscrasite continue to be discovered at intervals in this interesting mine; quite recently (September and October, 1900) about two tons of it were extracted, and in 1899 a rich patch was also unearthed, including a slug of chloride of silver, weighing 600 lb.

Mr. George Smith, who was for some years the General Manager of the mine, contributed an interesting description of the deposit to the American Institute of Mining Engineers in 1896. The following extracts are from the paper referred to:—

"All the ore yet won has been confined to those portions of the lode which are enclosed in the amphibolite, and the boundaries of this rock have been proved to be identical with the limits of the ore-bearing shoots. Where the metamorphic rocks have been intersected the lode invariably pinches, sometimes showing no more than an inch seam of flucan. . . . The ores of the mine exhibit many varieties, some of which have not been found elsewhere in the district—or, in fact, in Australia; but, with four exceptions, these rare minerals occur in small quantity. . . . The following are the most important, and are named in the order of their productiveness:—

| | Silver contents. |
|---|---|
| 1. Stromeyrite... ... ... | ... about 30 per cent. |
| 2. Dyscrasite ... ... ... | ... 72 to 94 ,, |
| 3. Antimonial silver chloride | ... 50 to 76 ,, |
| 4. Fahlerz ... ... ... | ... about 20 ,, |

"A peculiar fact in connection with the ore-bodies is their constant association with small quantities of cobalt-minerals. They are apparently inseparable; and, to the best of my recollection, neither has been found without the other. Where it occurs within the zone of oxidation, the cobalt ore is more or less altered, and is then often argentiferous, sometimes to the extent of five per cent.; but, as a rule, it does not occur in immediate contact with the silver ore, but in a separate vein of lode material either above or below the latter. Below this zone the cobalt is almost solely in the form of cobaltite, and though it has been found in intimate mechanical mixture with the silver ore, it is practically free from the latter when in its altered state. . . . . In that band of diorite (amphibolite) which contains the shoot most extensively worked, two separate and parallel cross-veins have been found; but, unlike the *indicators* of Victoria, neither is continuous. Their course is, approximately, north-east and south-west, following the direction of the shoot, and wherever they have been met with, valuable deposits of silver have been found at the points of their contact with the lode. The larger of these falls vertically on the lode, and is composed of varying proportions of blende, pyrites, &c., with quartz; the thickness ranging from a mere streak to over three feet. By far the largest bonanzas yet found were in association with this cross-vein. . . . . Both the cross-veins have been found to cut out, and make again at irregular intervals for a considerable distance. . . . . The larger cross-vein, which is shown in the sketch, has been faulted by the lode; and though it has been traced in an almost direct line for nearly 600 feet, it would probably be more correctly described as a succession of rock-joints formed along a line of weakness, and enlarged in places by a process of removal and replacement. . . . . In another part of the mine, 500 feet to the east, a separate shoot is being worked, which has yielded the same class of silver compounds, deposited under similar conditions. This shoot is crossed almost at right angles by a veritable cross-vein of pyrites; and though this vein presents




A. Dyscrasite. B. Stromeyrite. C. Decomposed amphibolite, &c., assaying under 7 oz. per ton. D. Fahlerz. E Soft gossany material, containing nodules of silver chloride, stromeyrite, &c., and averaging about 750 oz. per ton. F. Limonite--practically free from silver. G. Cross-veio. H. Amphibolite.

CROSS-SECTION OF AUSTRALIAN BROKEN HILL CONSOLS LODE.

(After Mr. George Smith.)

certain slight dissimilarities to those above referred to, its effect upon the silver solutions appears to have been exactly the same; the ore occurring at the point of its junction with the lode. It will thus be seen that wherever the cross-veins have been found to make junctions with the lode, valuable deposits of silver have been found, and no important find has yet been made except where a cross-vein has been in evidence. The lode gangue is very often composed of most 'kindly' material, which, as a rule, is practically free from silver (averaging less than half an ounce per ton), up to within a very short distance of the ore bodies. It must, therefore, be admitted that, whatever may have been the direct cause of the deposition of the silver, the cross-veins have played an essential part in the process. . . . Practically the whole of the dyscrasite has been found crystallised; some of it, especially that occurring in calcite, being of great beauty. The most common varieties contained definite proportions of antimony and silver, as will be seen by the following analyses made of typical crystallised specimens :—

| | | Silver, per cent. | | Antimony, per cent. | | | |
|---|---|---|---|---|---|---|---|
| No. 1 | = | 72·9 | ... | 27·1 | Agreeing with the formula | | $Ag_3Sb$ |
| No. 2 | = | 78·3 | ... | 21·7 | Do | do | $Ag_4Sb$ |
| No. 3 | = | 84·4 | ... | 15·6 | Do | do | $Ag_6Sb$ |
| No. 4 | = | 91·5 | ... | 8·5 | Do | do | $Ag_{12}Sb$ |
| No. 5 | = | 94·1 | ... | 5·9 | Do | do | $Ag_{18}Sb$ |

"The antimonial silver chloride is a specially interesting mineral, inasmuch as it carries with it certain evidences of alteration, from which much of its history can be gathered. All the deposits yet found have unmistakably shown it to be the result of alteration of dyscrasite. As I have previously observed, it is evident that the solutions which originally coursed through the lode must have been very varied. In a measure, the effects of each can be traced by its varying action upon those minerals that were most susceptible to its attacks. The particular solutions that have resulted in the mineral now under notice would seem to have contained certain quantities of lime, magnesia, iron, &c., as chlorides probably; and they would, therefore, be very similar to those at present existent in the mine."

Duplicate analyses of the mineral referred to by Mr. Smith were made in the Laboratory of the Department of Mines, Sydney, by Messrs. Mingaye and White, with the following results :—

| | No. 1. | | No. 2. |
|---|---|---|---|
| Moisture at 100° C. | 0·56 | ... | 0·13 |
| Combined water | 4·04 | ... | 4·37 |
| Silver | 47·46 | ... | 45·87 |
| Antimony | 16·87 | ... | 20·72 |
| Copper | ·11 | ... | ·48 |
| Lead | ·62 | ... | ·31 |
| Arsenic | trace | ... | trace |
| Gold | trace | .. | ...... |
| Lime | 3·78 | ... | 4·25 |
| Magnesia | 1·17 | ... | ·20 |
| Ferric oxide | 2·11 | .. | ·45 |
| Chlorine | 13·69 | ... | 12·27 |
| Insoluble (gangue) | 1·01 | ... | ·90 |
| Oxygen (by difference) | 8·58 | ... | 10·05 |
| | 100·00 | ... | 100·00 |

The mineral is apparently a mechanical mixture of chloride of silver with antimoniates of silver, copper, lead, lime, and magnesia. On treating some of the powdered material with strong ammonia, the chloride of silver was practically all removed, leaving the antimoniates as an insoluble residue.

*Webb's Silver Mine.*—This mine is situated on Little Plant Creek, in the Parish of Strathbogie North, County of Gough, about seven miles N.W. by N. from the town of Emmaville, and was discovered in the

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but this is compensated for by the fact that the proportion of fahlerz is also increasing. An analysis of a sample of the fahlerz, made by Mr. J. C. H. Mingaye, in the Laboratory of the Department of Mines, gave the following results:—

| | | |
|---|---|---|
| Copper ... ... ... ... ... | 31·500 | |
| Antimony ... ... ... ... | 18·130 | |
| Zinc ... ... ... ... ... | 6·140 | |
| Iron ... ... ... ... ... | 6·440 | |
| Lead ... ... ... ... ... | ·680 | |
| Silver ... ... ... ... ... | 1·635 | = 534 oz. per ton |
| Sulphur ... ... ... ... | 26·180 | |
| Insoluble in acids ... ... ... | 7·200 | |
| Traces of arsenic, gold, undetermined | 2·095 | |
| | 100·000 | |

One of the features of these lodes is that, as a general rule, there is no evidence of the existence of walls; at very rare intervals what appears to be a fairly-defined wall (but without slickensides or other signs of movement) is met with on one or other side of the lode, but it is never found to extend for more than a few feet, either longitudinally or vertically, and on either end of it the lode is found to merge into the country rock, the bedding and joint planes of the latter extending uninterruptedly across the former. In short, the only apparent difference between the lodestuff and the country is that the one is grayish-white, and impregnated or seamed with ore, while the other is bluish-gray, and contains little or no mineral; consequently, where the deposit has been worked out, the sides of the stopes present a very rough and jagged appearance. Occasionally isolated veins of ore extend into the country rock for some distance from the sides of the lode, but, as a rule, it does not pay to follow them. The lode is said to be invariably poorer where there is any evidence of a wall occurring.

In the stopes, at the 440-feet level a flucan or cross-course can be seen intersecting the lode at right angles, and dipping N. 20° E. (the direction of the strike of the lode) at an angle of about 40°. This cross-course may have produced a downthrow of the northern portion of the lode, though there has been no apparent lateral displacement, owing to the verticality of the lode, and to the fact that the plane of the cross-course is at right angles to it. The cross-course does not appear to have had any effect upon the mineral contents of the lode.

It would appear that these deposits owe their origin to parallel fissures, with more or less ragged or uneven sides, which occurred in the highly-inclined bluish-gray claystones, cutting across them in a direction nearly at right angles with their bedding planes; that the claystones between two parallel fissures were considerably fractured at the time the fissuring took place, but that no vertical movement of any consequence

*Photographed by E. F. Pittman.*

WEBB'S SILVER MINE, LITTLE PLANT CREEK, NEAR EMMAVILLE.

The clean concentrates constitute about ten per cent. of the crushed ore, and at the present time about twenty-seven tons of them are produced per week. After the moisture has been expelled on a drying-floor they are bagged and carted to Deepwater (26 miles), and thence by train to the Dapto Smelting Works, where they are purchased on the basis of their assay value. Their average composition is as follows:—

| | | |
|---|---|---|
| Silver | ... | 112 ounces per ton. |
| Lead | ... | 7 per cent. |
| Copper | ... | 4 ,, |
| Zinc | ... | 13 ,, |
| Arsenic | ... | $9\frac{1}{2}$ ,, |
| Antimony | ... | $7\frac{1}{2}$ ,, |

There are about twenty thousand tons of old tailings at the mine, which are said to contain on an average ten ounces of silver per ton. It is proposed to erect a plant, consisting of rolls, trommels, and jigs, for the purpose of re-treating these.

There can be very little doubt that some capital might be judiciously expended in properly opening up this mine (so as to allow of its being worked by overhand stoping), in the installation of a rock-drilling plant, and in the improvement of the concentrating machinery; the outlay would probably be soon justified by the increase in the returns.

*Pye's Creek Argentiferous Deposits.*—At Pye's Creek, twenty-one miles north-east of Emmaville, silver lodes occur of a somewhat similar character to those at Little Plant Creek, but the ore at a depth consists principally of argentiferous galena with some zincblende and fahlerz. It was confidently expected by those interested that these lodes would prove to be valuable properties, but hitherto they have not been worked with much success. The high cost of carriage in this district, and the present low price of silver, are serious drawbacks, and render it difficult to treat these ores with a margin of profit; but there is no doubt that they, as well as many of our other argentiferous deposits, will yet be worked under more favourable conditions.

*Webb's Consols Silver-mine.*—The deposits formerly worked by the Webb's Consols Silver-mining Company were discovered about the year 1885, and are situated about eleven miles to the south of Emmaville, in the parish of Gordon, county of Gough. Three distinct lodes are known to exist on M.L. portions 1,015, 1,018, and 1,019. The country rocks consist of granite and quartz porphyry, and the lodes, which are variable in width, have a north and south strike and are nearly vertical.

The principal lode, which is also the one on which the most work has been done, is on portion M.L. 1,015 and strikes about N. 10° E. Its gangue consists of quartz and felspathic material containing bunches, veins, and impregnations of galena, mispickel, copper pyrites, and zinc-blende. The main shaft is 209 feet deep, and at the 75-feet level a drive was put in to the north, and communicates with the bottom of another shaft about 70 feet distant. The workings are at present full

*Photographed by E. F. Pittman.*

WEBB'S CONSOLS SILVER MINE, WITH MOUNT GALENA IN THE BACKGROUND.

Ten miles south of Emmaville.

of water, as mining operations have been stopped for several years. The lode is understood to have been a wide one, and is said to have been 13 feet in width at the bottom of the main shaft.

Some of the veins of galena were as much as four feet wide, and this ore was of good quality ; two parcels of 20 tons each were sent away in 1888, viz., one to Adelaide, and one to Germany, and the average gross returns from these are said to have been 73 ounces of silver per ton, and 66 per cent. of lead. Other bulk samples were afterwards sold to the Aldershot Smelting Works, near Maryborough, and the returns are understood to have been somewhat similar. Thus in 1889 forty tons of concentrated argentiferous galena were sold, averaging 70 ounces of silver per ton, and 68 per cent. of lead ; in 1890 more ore was raised. Thus according to the Mining Registrar's report there were about 560 tons of ore produced, and of this 270 tons were treated for a return of 4,070 ounces of silver, and 38½ tons of lead. During the year 1892, the mine produced in five months ore to the value of £1,100, one lot of 27 tons being sold at Aldershot Smelting Works for £375 18s. 4d. Mining operations were then stopped ; it was found that as the workings became deeper the proportion of zincblende increased, and at the bottom of the main shaft where the lode had a width of about thirteen feet, large quantities of massive zincblende occurred. There was, at the time, no sale for such ore, and the percentage of galena not being sufficiently high to pay for working expenses, the mine was abandoned. It is possible that further prospecting would result in the discovery of other deposits of argentiferous galena, and the massive zincblende, which appears to be easily separated, and some tons of which are now lying at the surface, should be made a valuable product as an ore of zinc if any further attempt be made to work this mine. The silver contents of the zincblende are apparently not very high ; a sample of it was recently taken from the heap at the surface, and on being assayed in the laboratory of the Department of Mines, it was found to contain at the rate of 11 ounces 8 dwts. 16 grains of silver per ton, and no gold.

The reducing and concentrating plant of the Webb's Consols Company was evidently of a most primitive description, and in view of this fact, the cost of freight, and the uncertain market which then existed for the products, it is not surprising that the attempt to work the mine was a failure.

To the west of the principal mine two other north and south lodes occur in M.L. portions 1,018 and 1,019 respectively, and shafts approximating to 100 feet in depth have been sunk on each of these. No galena, it is understood, was discovered in either of these lodes, which appear to be of considerable width, and to consist of felspathic material impregnated with considerable quantities of mispickel, and a small percentage of copper pyrites. A sample of the mispickel recently taken from the spoil heap of one of the shafts was assayed in the Mines Department laboratory, and yielded at the rate of 7 ounces 11 dwts. of silver and a trace of gold per ton.

*Mount Galena Lode.*—Immediately adjoining the Webb's Consols mine on the east is a granite hill known as Mount Galena in which somewhat similar deposits have been worked. Two shafts have been sunk on portion M.L. 1,012, each to a depth of about 100 feet. In the most southern of these the only ore obtained was mispickel; but in the northern shaft some very large bunches of galena were met with, and a considerable quantity of this was sent to the Aldershot Smelting Works, near Maryborough, Queensland; the returns are not available, and as far as can be ascertained they did not realise sufficient to cover the cost of mining and freight. The mine was finally abandoned because the bunches of galena gave out, leaving nothing but mispickel. Nevertheless, it is probable that similar bunches of galena would be found if more extensive prospecting operations were undertaken.

Further south, on M.L. 1,013, is a small open quarry, known as Barton's quarry, in which, it is said, small bunches of galena were obtained; but at the present time only veins of mispickel can be seen in the walls of the quarry.

*Wellingrove Silver-lead Mine.*—This mine is situated about one mile due east of Mount Galena, on portion 8, parish of Gordon, county of Gough. A lode having a north and south strike and dipping to the east at a considerable angle, has been traced on the surface for a distance of a mile or more, and is being prospected by a syndicate of Inverell residents. A shaft has been sunk to a depth of 150 feet, showing the lode to have a width of three feet. The gangue consists of felspathic material, and it contains streaks, veins, and bunches of galena, with a small proportion of zincblende. A sample of the solid galena was recently taken at the mine, and yielded by assay in the laboratory of the Department of Mines 23 ounces 19 dwts. of silver per ton. A bulk sample of 18 tons of ore (chiefly carbonate of lead) from this mine was recently treated at the Cockle Creek works, and the return was 40 per cent. of lead, 5 ounces of silver, and 1 dwt. of gold per ton.

*The Rivertree Silver Lodes.*—The argentiferous lodes of Rivertree were discovered in the year 1887, and are situated on the Upper Clarence River, in the Parishes of Clarence, Reid, Strathspey, and Cataract, County of Buller.

This field has recently been examined by Mr. E. C. Andrews, Geological Surveyor, who reports that the country consists of slate, which has been intruded by granites of different ages in the form of bosses and tongues, and these in turn have been intersected by dykes of diorite and granite. Sometimes the lodes are contained in solid granite of one age; in other cases granite and diorite, or diorite and slate, form the walls. In these latter cases the deposits occur as contact lodes along the junctions of the various rocks. The surface of the country is very much broken, the variation in the altitudes of different lode outcrops being as much as twelve hundred feet.

The lodes strike across the field for great distances in nearly parallel lines, their direction varying between N. 30° W. and N. 45° W. Their general dip is south-westerly, although one or two lodes, such as the Wongabah and MacDonald's, dip north-easterly.

The ore-bodies are contained in true fissures which traverse both slate and granite country indifferently. In some cases the iron-stained outcrops of the lodes are traceable on the surface for distances of one or two miles. The lodes are characterised by well-defined walls, and at depths of two hundred feet they have every appearance of permanence.

At the outcrops the lodestuff consists of quartz and gossan, with carbonate of lead and some chloride of silver (cerargyrite), and proustite. The ores have been affected by the oxidising influence of the atmosphere down to depths of only ten to thirty feet. The commoner minerals forming the argentiferous ores in the unoxidised zone are galena, zinc-blende, mispickel, and iron pyrites. In the slate country, argentiferous galena and stibnite occur, with small quantities of proustite (light red silver ore) and argentiferous fahlerz. There are indications that zinc-blende becomes more plentiful in the lower levels, though the greatest depth yet attained is only two hundred and ten feet. The gangue consists of quartz and granitic derivatives, and throughout this the ore occurs in lenticular veins, generally a few inches in thickness.

The lodes vary in width from several inches up to two feet, and occasionally as much as four feet. The lenses of ore are uncertain both in size and value, and large spaces of valueless gangue are often met with between them, necessitating a considerable amount of deadwork. The silver contents of the lodes vary from a few ounces up to two hundred or three hundred ounces per ton.

Amongst the principal lodes on the field are the Phœnix, the Mount Pleasant, the Dunlop, the Wongabah, MacDonald's Wongabah, and the Philippines.

The first attempt made to recover the silver from the Rivertree ores was by means of a water-jacket smelting-furnace, which was erected in the year 1890. The experiment, however, was unsatisfactory both in regard to the cost of treatment and the proportion of silver obtained; the reasons assigned being the siliceous character of the ore, and the expense of procuring coke and fluxes (ironstone and limestone). Subsequently the Rivertree Proprietary Company erected extensive works at a cost of about £14,000, with the object of leaching the ore by the Russell process, using the White-Howell furnace for chloridising-roasting. It was found, however, that the cost of this method of treatment was prohibitive, except for the high-grade ores, and consequently large quantities of silver ore have been stacked or discarded.

The Rivertree deposits suffer from the disadvantage of being situated in a very rough and remote district, as will be understood when it is stated that ore containing less than sixty ounces of silver per ton will not bear the cost of conveyance to, and treatment at, the Cockle Creek

Smelting Works. It is said that between £60,000 and £70,000 has been expended on the field in machinery and development, but so far it can hardly be said that mining operations have been successful. There can be no doubt, however, that in the future, with improved means of transit, many of these lodes will be worked with successful results.

*The Boro Creek Silver Lode* is situated about seven miles south-east of Tarago, a station on the Cooma railway line. It was during the "silver boom," early in 1888, that the deposit was opened by Griffin and Party, whose attention was attracted by an outcrop of gossan (limonite) about fifty feet in width. A shaft was put down to a depth of seventy feet, and the mine was then sold to a Sydney syndicate (Miller and Party) for the sum of £500. Several tons of carbonate of lead ore were extracted and sent for treatment to the Clyde Smelting Works, and the returns are said to have been about 35 ounces of silver per ton, and 22 per cent. of lead. The shaft was then sunk to a depth of 120 feet, and crosscuts were put in to the east and west, disclosing a wide formation with medium grade carbonate ore throughout. In a shaft sunk to a depth of seventy feet in the gossan small quantities of chloride of silver were obtained, but assays of the ironstone in this and another shaft (35 feet deep) yielded only from five to seven ounces of silver per ton, and a trace of gold. Government aid was then obtained to sink the main shaft to a depth of 160 feet, and although rich strings of argentiferous cerussite were obtained, no defined lode was met with.

At a distance of about 200 yards south of the main shaft another shaft was excavated to a depth of seventy feet, and a crosscut to the westward from the bottom of this is said to have intersected the ironstone lode, containing veins of manganese oxide with chloride of silver.

About 550 feet still further south an open cut was made across an outcrop of ironstone which showed traces of chloride of silver in vughs. A very rich irregular *chute* of chlorides was afterwards struck here by tributors, and was followed by them down to a depth of sixty-five feet.

Work at the mine was stopped in the year 1892, and was resumed by tributors in 1897–98, when three or four hundred tons of ore were extracted; the greater portion of this ore was taken from the seventy-feet level of the main shaft, and is said (by Mr. Miller) to have yielded from 25 to 30 ounces of silver per ton, and 18 per cent. of lead.

Water was met with in the main shaft at a depth of 135 feet, and the cessation of mining operations by the syndicate was due to their not being provided with sufficient funds to erect pumping machinery.

No sulphide ores were ever met with, and the prospecting operations were not carried deep enough to prove whether a defined lode really exists here or not, though from the occurrence of the bold outcrop of gossan, and the reputed yields of chloride of silver from the carbonate of lead, it seems probable that there is one.

*The Walla Walla Silver Lodes.*—These deposits are said to have been known for a considerable number of years, but it was not until 1888 that much attention was directed to them. They are situated in the Parishes of Opton and Ware, County of King, near Rye Park, and about twenty-eight miles north of the town of Yass.

The lodes intersect beds of altered slate and sandstone, near their junction with a mass of intrusive quartz porphyry. The slates and sandstones are probably a continuation of the sediments which are so well developed in the neighbourhood of Yass, where they contain trilobites and many other fossils of Upper Silurian age.

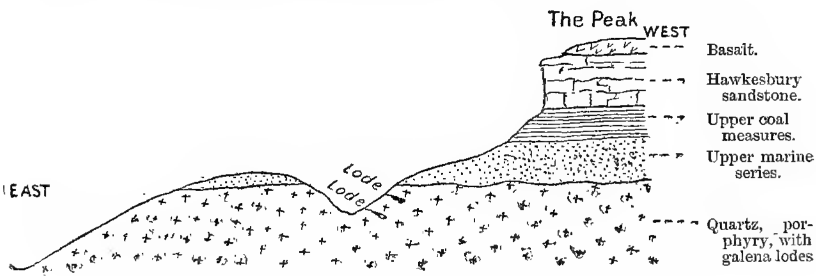
A considerable area of ground was applied for under the Mineral Lease Regulations in 1888, but prospecting operations were not carried out to any considerable extent except in one or two cases. No machinery was erected on the ground, and whatever ore was extracted was merely hand-picked and despatched to the Clyde Smelting Works for treatment. The most work was performed by a syndicate known as the Walla Walla Proprietary Silver-mining Company, and prior to April, 1891, one hundred and forty-two tons of ore from their mine was sold, and is said to have yielded 5,290 ounces of silver (or at the rate of 37¼ ounces per ton), and forty-nine tons of lead. In addition to this, four hundred and fifty-four tons of ore, which were raised but not sold, are said to have contained at the rate of twenty-nine ounces of silver per ton, and twenty-five per cent. of lead. Mining operations were then stopped for some years, but were resumed in October, 1897, and, from that date to October, 1899, two hundred and seventy-one tons of ore were sent to the Cockle Creek Works, and are said to have yielded a net return of £689 10s. 8d.

Quite recently the property has been acquired by a company called the Walla Walla Silver and Lead Mines; it consists of three blocks (M. Ls. 110, 111, and 113) of forty acres each. The lode shows a well-defined outcrop consisting of limonite gossan, which, when broken, is seen to be stained green in places with mimetite (arseniate and chloride of lead). The lode is nearly vertical, and its strike is about N. 5° E. There are five shafts, the deepest of which is one hundred and fifty feet, and drives have been put in at the fifty and one hundred feet levels.

The oxidised portion of the lode contains cerussite (carbonate of lead), pyromorphite (phosphate and chloride of lead), mimetite, galena, zinc-blende, and mispickel, with a little copper pyrites and stains of carbonate of copper. At the one hundred feet level bunches of earthy-black oxide of copper, one foot in width, are met with, and crystals of sulphate of copper and sulphate of iron are also occasionally seen. Massive sulphide ores occur in lenticular bunches, and these consist chiefly of arsenical pyrites (mispickel) and galena, with some zincblende and quartz.

The width of the lode is variable; in some places it has been proved to be eight feet wide, while in others it thins out altogther. At the fifty feet and one hundred feet levels the lode shows the full width of the drive, and is bounded on either side by slate; but where this has been pricked through for a depth of a foot or two galena is seen to be present beyond it. It is evident, therefore, that "horses" of country rock occur in the ore-bodies, and, until the deposit has been tested by crosscuts, it would be impossible to estimate its average width. All that can be said in the meantime is that the lode has the appearance of being permanent, and that it will probably consist, in the deeper levels, of mixed sulphides, such as mispickel, argentiferous galena, zincblende, and copper pyrites in a quartz gangue. The company are about to erect a small pumping and winding plant, all the work having hitherto been performed with a whip and windlasses.

*The Burragorang Silver Lodes.*—At The Peaks, Upper Burragorang, Parish of Colong, County of Westmoreland, silver lodes occur in quartz porphyry, which here forms the floor of the Permo-Carboniferous coal basin. The Wollondilly River has cut its course through the Hawkesbury Sandstones, the Upper Coal Measures, and the Upper Marine Beds successively; these rocks at one time covered the whole of this district, but they have all been removed by denudation from considerable areas of the watershed, leaving the underlying porphyritic rocks, and the argentiferous galena lodes which intersect them, exposed at the surface.




Geological Section of Country to the East of The Peaks.

Silver-bearing lodes were discovered in this locality about twenty-five years ago, and a considerable area of land was taken up at that time for the purpose of working them, but they were soon afterwards abandoned, owing to lack of facilities for treating the ore. In 1893 some of the land was again taken up, and a galena lode, known as Cuneo's Lode, was worked to a depth of 40 or 50 feet. The lode varied in width from an inch or two up to two feet six inches, and in its widest part it contained an average of 17 ounces 14 dwt. of silver per ton, and about 11·62 per cent. of lead. It was found that the ore required to be concentrated before it was in a fit condition for smelting; and, in view of that fact, the distance from the railway, and the extremely rough nature of the country, mining operations could not be profitably carried on.

*Photographed by E. F. Pittman*

BARTLETT'S SILVER LODE, THE PEAKS, BURRAGORANG.

More recently several other lodes have been discovered, by Messrs. Webb and Bartlett, on H. C. Manning's Conditional Lease, and a number of authorities to mine, under the Mining on Private Lands Act, were granted. The establishment of smelting works at Dapto (Illawarra), and at Cockle Creek, near Newcastle, has enabled the owners of these mines to have a practical test of the value of the ores, and although the expenses of cartage, railway freight, and smelting charges have proved a severe handicap, the results have shown that the prospects of the field are considerably more promising than they were in 1893.

Bartlett's mine, known as "The Peaks Proprietary Gold and Silver Mine," is the one from which the most satisfactory results have, so far, been obtained. In June, 1899, two shafts had been sunk to depths of 110 and 130 feet respectively, on the underlie of a lode which strikes about east and west, and dips to the south at an average inclination of about 25°. About 458½ tons of ore were extracted from this mine, and treated at the Dapto and Cockle Creek Smelting Works, prior to the 1st September, 1899, for a net return of 32,344 ounces of silver, 55 ounces of gold, and 49½ tons of lead. The following are the complete returns :—

| Weight. | | Gold. | | | Silver, | | | Lead. | | | | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tons | cwt. | oz. | dwt. | gr. | oz. | dwt. | gr. | ton | cwt. | qr. | lb. | |
| 132 | 14 | 14 | 6 | 4 | 6,788 | 16 | 11 | 6 | 19 | 3 | 5 | 36 tons low-grade ore. |
| 165 | 3 | 25 | 15 | 11 | 10,837 | 0 | 16 | 12 | 1 | 0 | 12 | Fair quality. |
| 136 | 14½ | 13 | 1 | 16 | 12,634 | 19 | 21 | 25 | 6 | 0 | 25 | Better quality. |
| 24 | 0 | 2 | 9 | 23 | 2,083 | 3 | 21 | 5 | 4 | 3 | 1 | ..................... |
| 458 | 11½ | 55 | 13 | 6 | 32,344 | 0 | 21 | 49 | 11 | 3 | 15 | |

The above figures represent net values after deduction by smelting works of 2 dwt. of gold per ton, 10 per cent. of silver, and 20 per cent. of lead.

The lode is very variable in width, thinning out to one inch in places, and occasionally widening to as much as five feet. The character of the lodestuff is also variable, for, in some places, the channel is almost entirely filled with rubble or mullock ; in others it is formed of quartz, impregnated with argentiferous galena ; and again in others, extensive bunches of massive galena, carrying a high proportion of silver, almost entirely replace the quartz. In one of the inclined shafts the lode, which was followed from the surface, widened out from one inch to five feet in thickness at a depth of 106 feet ; the ore was of poor quality until a depth of 50 feet was reached, when good galena ore was obtained on the western side of the shaft, and an area of ground 45 feet long, with an average width of about 20 feet, was stoped out. The bunch of ore occurring here consisted of a thickness of 2 feet 6 inches of nearly solid galena (with streaks of quartz) carrying 100 ounces of silver and 5 dwt. of gold per ton, and 28 per cent. of lead. Below this was a band of mullock 1 foot 9 inches thick, and underneath this again was a thickness of 1 foot 6 inches of solid fine-grained galena carrying 30 per cent. of lead, with 100 ounces of silver and 5 dwt. of gold per ton. In another inclined shaft in the same mine the lode, at a depth of 127 feet, consisted of from 8 to 18 inches of solid galena, carrying 26 per cent. of lead, 104 ounces of silver, and 6 dwt. of gold per ton. Specks of copper pyrites could occasionally be seen in the ore, as well as traces of light-red silver ore (proustite).

In Webb's Mine the lode has a north and south strike, and dips to the west at an angle of about 20°. It varies in thickness from four inches to two feet, with occasional bunches, up to nine feet in thickness, of quartz containing a fair amount of galena with some stains of carbonate of copper. In general characters this lode very much resembles Bartlett's, except that its course is almost at right angles to the latter. More development work has been carried out on Bartlett's Lode, and, consequently, more solid galena ore has been discovered. About 60 tons of ore were sent away from Webb's Mine and realised £600.

In Hilder's Mine, an east and west lode, which is probably identical with Bartlett's, has been opened to a depth of 200 feet in an underlie shaft. The channel has frequently a width of four feet, but so far only about 1 foot thick of solid galena has been found, the remainder of the filling consisting of either rubble or quartz. In places, exceedingly rich deposits of native silver have been found associated with the galena, and some proustite (Light Red Silver Ore) is also occasionally seen.

There are several other mines in which similar lodes are being prospected, but the amount of work done is not sufficient to enable an opinion to be formed as to the permanence or richness of the deposits.

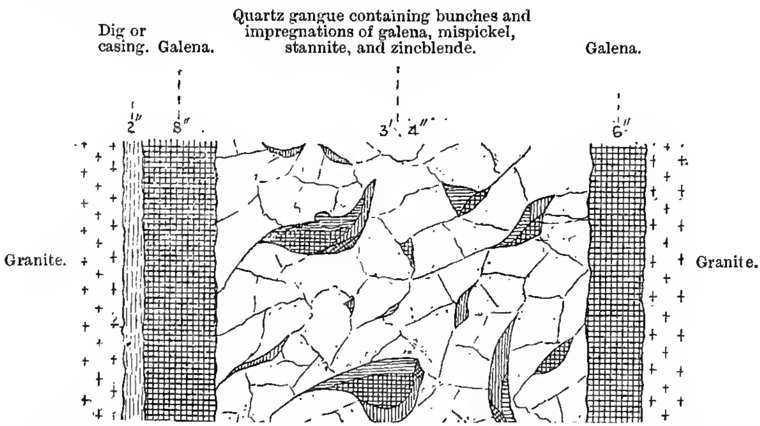
The cost of cartage of the ore from the mines to the nearest railway-station (Picton) is at present £2 5s. per ton. The road from the Peaks to the Wollondilly River is an extremely bad one, the grades being very steep, and the tracks rough. On the other side of the river, going towards Picton, the road, though in better condition for vehicles, contains some very steep grades, as it has to ascend a high mountain range.

From the foregoing brief description of the argentiferous deposits of Upper Burragorang, it will be understood that they are very variable in width and composition; the rich galena occurs in bunches, which may, or may not, be found to increase in number and size as the deposits are followed down. At the present time, sufficient work has not been done to establish their permanence in depth; on the other hand, it cannot be denied that Bartlett's Lode is of a very promising character, and there are several other lodes in the vicinity which may be expected to yield equally good returns when more work has been carried out upon them. With a view of encouraging the prospecting of these deposits, the Government have spent a considerable sum of money in the improvement of the road to the Peaks.

*Borah Creek Silver Lode.*—A valuable silver-bearing lode occurs at Borah Creek, in the Parish of Mayo, County of Hardinge, about seventeen miles in a southerly direction from the town of Inverell.

The deposit was discovered in the year 1890, but it was not until 1897, when the prospector's claim was purchased by Mr. John Howell (late General Manager of the Broken Hill Proprietary Silver-mining Company) that any systematic prospecting work was undertaken.

This lode occurs in granite country, and its outcrop has been traced for a distance of about five miles. It occupies, for a considerable length, the centre of a valley of erosion, the direction of the latter having evidently been determined by the circumstance that the cap of the lode was more easily denuded than the surrounding granite. In several places dykes of fine-grained aplitic granite occur in proximity to the ore deposit. The lode is very steeply inclined, being, in fact, almost vertical, and the direction of its strike is about N. 50° W. It varies in width from six inches to five feet, its average width being about three feet three inches. It is bounded, as a rule, by a dig or casing, which frequently shows striated slickensides. The casing varies from an inch to a foot or more in thickness, and is composed of greasy clay with a certain amount of grit; it is found sometimes on one wall, sometimes on the other, and, in some instances, on both. The fissure is not characterised by smooth walls, though occasionally one wall is fairly regular. The gangue consists of quartz, which frequently occurs as fine crystals in vughs. The ore contains a high percentage of silver, and consists of the following minerals, viz., galena, zincblende, copper pyrites, mispickel, and stannite. The following is a section of the lode at a depth of one hundred feet:—




SECTION OF THE BORAH CREEK LODE, CONRAD SILVER-LEAD MINING COMPANY.

There is frequently a band of argentiferous galena alongside one or both walls, while the different sulphide minerals already enumerated are distributed in patches throughout the quartz gangue.

It is remarkable that only very small quantities of oxidised ores were found in the upper portion of the lode. They consisted of red oxide, and blue and green carbonates of copper, while below these a little amorphous black oxide and native copper have been re-deposited from the solutions by which the natural leaching of the outcrop has been effected.

The ore occurs in *chutes*, which appear to be several hundred feet in length, but sufficient work has not yet been done to demonstrate whether they extend vertically downwards or dip at an angle. In some of these *chutes* the ore is principally galena ; in others it consists chiefly of chalcopyrite and stannite ; while in others, again, mispickel predominates. It has been noticed that when the lode takes a south-westerly dip it is characterised by increased richness, but until considerably more work has been done it would be premature to assume that this rule holds good throughout the deposit.

The principal mines at present being worked on the Borah Creek Lode are the Conrad Silver-lead Mining Company and the King Conrad. The former was purchased and developed by Mr. John Howell, and comprises an area of sixty acres.

In the Conrad Mine the lode has been proved on the surface for a distance of 2,300 feet, and it has been driven on for 1,250 feet in length underground. The main shaft is one hundred feet deep, and from the bottom of it a crosscut has been put in to intersect the lode, and at this level there is a drive along the course of the lode for 160 feet to the north-west, and 700 feet to the south-east. A winze has been sunk in the lode for a depth of seventy feet from the 100-feet level, so that the greatest depth yet attained is 170 feet from the surface ; at this depth the lode maintains its average width and richness.

The reduction and concentrating plant consists of a Blake rock-breaker Cornish rolls, Trommel, May jigs, and Wilfley vanners. The ore, as it comes from the shaft, is thrown on a grizzly ; the coarser material is then hand-picked, and the richer portion of this goes to the rock-breaker, and thence to the rolls, &c. ; about fifty-five per cent. of the ore passes through the grizzly and direct to the rolls. After being crushed in the rolls, the ore passes to the trommel ; the coarse material from the latter is elevated and put through the rolls again ; the "fines," which pass through the screens (six holes to the inch) of the trommel are treated in May jigs fitted with four compartments, which produce the following concentrates :—

| | | | |
|---|---|---|---|
| No. 1 Compartment produces galena concentrates. | | | |
| No. 2 | ,, | ,, | mispickel and lead concentrates. |
| No. 3 | ,, | ,, | copper and mispickel concentrates. |
| No. 4 | ,, | ,, | copper concentrates. |

The concentrates from No. 3 compartment are passed through the jigs again, and produce mispickel concentrates and copper concentrates.

*Photographed by E. F. Pittman.*

The Conrad Silver-Lead Mining Company, Borah Creek, near Inverell.

The tailings from the jigs are treated in Wilfley vanners, while the slimes pass from the jigs to settling-tanks, and the overflow from the latter is collected in the dam. Between three and four tons of ore are said to produce one ton of concentrates and slimes. The capacity of the mill is about 280 tons of ore per week. Samples of the different concentrates produced by the jigs were recently taken and analysed in the Laboratory of the Department of Mines. The results were as follows :—

Galena concentrates : Lead, 42·88 per cent. ; copper, 3·48 per cent. ; zinc, ·64 per cent. ; tin, 2·09 per cent. ; fine silver, 113 oz. 13 dwt. 14 gr. per ton.
Mispickel and lead concentrates : Lead, 20·50 per cent. ; copper, 4·95 per cent. ; zinc, 1·82 per cent. ; tin, 4·13 per cent. ; fine silver, 68 oz. 17 dwt. 10 gr. per ton.
Copper and mispickel concentrates : Lead, 11·93 per cent ; copper 11·42 per cent. ; zinc, 3·18 per cent. ; tin, 8·97 per cent. ; fine silver, 73 oz. 17 dwt. 1 gr. per ton.
Copper concentrates : Lead, 4·70 per cent. ; copper, 13·37 per cent. ; zinc, 5·04 per cent. ; fine silver, 63 oz. 11 dwt. 12 gr. per ton.

Besides the metals whose percentages are given, the concentrates contain arsenic.

The slimes are said to contain 48 ounces of silver, 5 per cent. of lead, and 3½ per cent. of copper.

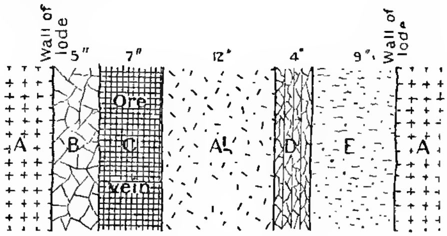
Up to the present time (August, 1900) about eleven thousand tons of ore have been raised and treated. The concentrates, up to a recent date, were sold, on the basis of their assay value, to the Cockle Creek Smelting Works, near Newcastle ; this involved sixty miles cartage to Glen Innes, and three hundred and thirty miles railway freight to the works. However, since the discovery of stannite in the concentrates, the Cockle Creek Smelting Company have been unwilling to purchase them, owing to the difficulty of dealing with such a complex ore. Doubtless, a process will soon be devised for its economical treatment, since it is of undoubted value ; and the operations of the Borah Creek Mines will be watched with great interest, as probably no similar combination of valuable metals on a large scale has ever been worked before.

The King Conrad Mine, which is situated to the north-west of the Conrad, has recently been floated into a company with a nominal capital of £200,000, and an extensive plant is about to be erected. The mine is opening up well, and, so far as the dimensions and composition of the lode are concerned, it appears to compare favourably with its neighbour.

In consequence of the success attending the opening up of the Borah Creek lode, prospecting has been vigorously carried out in the surrounding country, and quite a number of small "silver shows" have been discovered ; so far, however, none of these have been sufficiently developed to warrant their being referred to as payable mines.

*The Ruby Silver-mine, Rockvale.*—This mine is situated in the Parish of Chandler, County of Clark, about twenty-four miles to the north-east of Armidale. The lode was discovered early in the year 1895, by Baker Brothers and C. Wade, and was worked with considerable success by them for about two years and eight months, during which period they extracted silver ore of the gross value of about £17,000. The mine was then put under offer to the New Zealand Mines Trust, on a nine months' option, for a considerable sum of money, and it was eventually purchased by that Company.

The lode, which intersects granite rocks, strikes W. 35° N., and is almost vertical; its outcrop has been traced on the surface for a distance of over one thousand feet, but only the one mine has been worked with profit. The fissure varies in width from eight inches to four feet six inches, the average width being about two feet. The walls are fairly well defined, and show striated slickensides; a clayey casing occurs next the wall, and materially facilitates the breaking down of the lodestuff. The lode is banded in structure, and consists of hard quartz, laminated friable quartz, aplitic granite, and a vein of very rich silver ore. The following section of the lode was measured in the stopes between the 200 and 300 feet levels:—




A granite. A[1], aplitic granite. B, quartz. C, ore vein. D, friable quartz. E, clay dig or casing.

SECTION OF THE RUBY SILVER LODE, ROCKVALE.

The "ore vein" is the principal feature of the deposit, and without it the lode would not have been payable, although the quartz, or "formation," as the remainder of the filling is termed by the miners, also carries a certain proportion of silver ore. At the surface the ore-vein was four inches wide, and consisted chiefly of pyrargyrite and chloride of silver in gossan, assaying at the rate of over one thousand ounces of silver per ton. This continued to a depth of thirty feet, when the width of the vein increased to nine inches, and at eighty feet the ore changed to arsenical pyrites (mispickel), with pyrargyrite, proustite, and native silver (hair silver), beautiful nests of the latter being found in vughs. Occasionally very small quantities of iron pyrites and zinc-blende are found in the ore. The ore vein has been found to vary in width from two to nine inches, the average width being about four inches. Its assay value has varied from 150 to 1,250 ounces of silver per ton; the average, since the mine was sold by Baker Brothers, has been about 300 ounces per ton. Where the ore vein is rich, the quartz bands which bound it contain at the rate of from twenty-five to seventy-five ounces of silver per ton; but where the vein is poor there is a corresponding impoverishment of the quartz, and where the vein is absent the lode only contains from one to three ounces of silver per ton.

The position of the ore vein, in relation to the rest of the lode filling, is not constant; for the first hundred feet from the surface it adjoined the north-eastern wall, below that depth it crossed over to the south-western wall, and in the deeper levels it frequently occupies an intermediate position.

A feature of the mine, and one which appears to have had considerable influence on the ore-bodies, is a slide or plane of fracture, which intersects the granite rock, and also the lode in a direction at right angles to the latter. It was passed through in the main shaft, and was found to dip to the north-west at an angle of about 25°. In the vicinity of this slide the granite is much crushed and decomposed, so that great caution is necessary in mining operations. The ore vein has not been found to extend below this slide on the north-western side of the main shaft, and no payable ore has been found below the 200-feet level in this section of the mine; but on the south-eastern side of the main shaft the *chute* of ore extends below the 200-feet level, though its boundaries appear to be very irregular, and have not been ascertained completely as yet. It appears probable that this slide has faulted the lode in the direction of its strike, and that the ore *chute*, which has been worked from the surface to a depth of two hundred feet on the north-western side of the main shaft, formerly occupied a higher position.

The deepest shaft on the lode is only three hundred feet, at which depth no payable ore has been discovered; but it is very difficult to believe that the lode contains only one ore *chute*, and it is to be hoped that the New Zealand Mines Trust will see their way to deepen the shaft, and to drive in both directions, with the object of prospecting for ore-bodies.

The ore, as it comes to the surface, is hand-picked, the "firsts" being bagged, and forwarded by waggons to Armidale, and thence by train to the smelting-works at Cockle Creek, near Newcastle. The "seconds" are carted to the Phœnix Battery, two and a half miles distant; bere they are crushed and treated on Frue vanners, the concentrates being also sold to the Cockle Creek works.

### *Distribution of Silver Ores in New South Wales.*

The following is an alphabetical list of the localities from which specimens of silver ores have been received for assay in the Department of Mines:—

Abercrombie Ranges.
Abercrombie River.
Aconite, Parish of, County of Hardinge.
Adaminaby, near.
Adelong Creek.
Albury (Black Range).
Annandale, Parish of, County of Clive.
Armidale, near.
Armidale (Puddledock).
Ashford, near.
Back Creek, Rockley District.
Bald Hills, Forbes.
Bald Nob.
Barraba, near.
Barrier Ranges.

Bathurst, near.
Barney Downs.
Bee Mountain, Cobar District.
Bega.
Belara.
Bemboka.
Bendemeer, near.
Bell River.
Bellinger (Deep Creek).
Bellinger River.
Bermagui River.
Bertbong.
Beverly.
Billagoe, forty miles north of Cobar.
Binalong.
Binbanang (Glanmire).
Binda District.
Bingara.
Black Bullock Mountain, near Oberon.
Black Mountain, Armidale.
Black Range, Albury.
Bland (Sandy Creek).
Blayney.
Blythe, Parish of, County of Clarke.
Bobadah.
Bodangora Mountain.
Boggy Camp, near Inverell.
Bolderogery.
Bolivia.
Bollara.
Bombala.
Boonoo-Boonoo.
Boorolong.
Boorook.
Borah Creek.
Boro Creek.
Bowra district.
Braidwood, near.
Bredbo.
Brewongle.
Brewarrina.
Brindabella.
Broken Hill.
Brooke's Creek, Upper Gundaroo.
Broula.
Bulga.
Bull Dog Range, Mitchell's Creek, Bathurst District.
Bundarra.
Bungonia.
Burra-Burra, thirty miles north-east of.
Burraga.
Burragorang.
Burrowa.
Burrowa, twenty miles east of.
Byng.
Caloolah, near Trunkey.
Camden, near.
Candelo.
Cangi, near Grafton.
Canoblas, near Orange.
Captain's Flat.
Carangara (Byng).
Carcoar.
Casino.
Castlerag, near Deepwater.
Cell's Creek, Port Macquarie.
Chandler, Parish of, County of Clarke.
Chichester River.
Clarevaulx, near Glen Innes.
Clarence Heads, forty miles south of.
Clear Creek.
Clive, County of.
Cobar.
Collington.
Condobolin.
Cookbundoon.
Coolah.
Coolamon Plains.
Coolongolook.
Cooma.
Coonabarabran.
Cope's Creek.
Coppabella.
Costigan's Mount.
Corona.
Cowley, County of.
Cowra.
Cox's River, twelve miles from Hartley.
Crookwell.
Crudine.
Cullen's Creek.
Cumnock, near.
Dalmorton.
Darby's Run, near Tingha
Deep Creek, Nambucca
Deepwater, near.
Delany's Dyke.
Delegate.
Denison Town.
Diamond Heads, Manning River.
Digger's Creek.
Dilga River.
Dorah Creek.
Drake (White Rock).
Drake (Red Rock).
Drysdale, near Cobar.
Duckmaloi, near Oberon.
Eldorado, near Drysdale.
Elsmore.
Elsmore, Parish of, County of Gough.
Emmaville.
Emu Swamp Creek.
Eugowra.
Eurongilly.

Fairfield.
Fish River Creek.
Flyer's Creek, Carcoar District.
Forbes.
Frogmore.
Gilgunnia.
Gillana, Braidwood.
Glenburn.
Glencoe.
Glen Elfin, near Glen Innes.
Glen Innes.
Goran Lake.
Gordon.
Goulburn, near.
Gowonglah.
Grabben Gullen.
Grampians, The (New England).
Grenfell District.
Green Swamp.
Gulgong.
Gumble.
Gundagai.
Gunning.
Guyong.
Hampton.
Hartley, near.
Hastings River.
Hazlegrove, near Oberon.
Hillgrove, near.
Horseshoe Bend, Clarence River.
Humewood, near Yass.
Ilford, near.
Inverell.
Isis River.
Jarrow Creek.
Jenolan.
Jerrara Creek.
Jingellic.
Jinglemoney, near Braidwood.
Junee.
Kempsey, near.
Kempsey, fifteen miles west of.
Kiandra.
Kimo.
Kingsgate Run, near Glen Innes.
Kooringbury Gap.
Kydra.
Lake Bathurst.
Land's End Creek, Glen Innes.
Larry's Hill.
Lawson.
Leadville.
Lewis Ponds, near Orange.
Liliwa, Cudgegong.
Limestone Hill, near Braidwood.
Lismore and Ballina, between.
Little Hartley.
Locksley.
Macleay Heads.
Macleay River.
Major's Creek.
Mann River (The Bluff).
Manning River.
Markdale, near Crookwell.
Marulan.
Matong Station, near Cooma
Mayo, Parish of, County of Hardinge.
Meadow Flat.
Melrose.
Melrose, thirty miles from.
Menindie.
Menindie, Topaz Station, thirty-seven miles from.
Merimbula.
Michelago.
Middle Creek.
Milparinka.
Mitchell's Creek.
Mitta Mitta.
Mole River.
Molong.
Molonglo.
Moonabah, Macleay River.
Moonbi.
Mount Boppy, near.
Mount Bullen, Queanbeyan.
Mount Costigan.
Mount Galena, near Emmaville.
Mount Gipps.
Mount Grosvenor, near Peel.
Mount Opperaby.
Mount Sperraby, Bolivia.
Mount Stewart.
Mount Tinda, near Condobolin.
Mount Werong.
Moruya.
Mudgee.
Murrumburrah.
Murrurundi.
Muttama.
Nambucca.
Narrangarie.
Native Dog Creek.
Newbridge.
Newbridge, ten miles north of.
Newstead.
Nimitybelle.
Nine Mile, Deepwater.
Nobby Point, Port Macquarie.
Noioro.
Nowra.
Nundle.
Nuntherungie.
Nymagee District.
Oban, near.
Oberon.
O'Connell.
One-Tree Hill.

Ophir.
Orange, near.
Orange (Bulga)
Panbula.
Parkes.
Palmer's Oakey.
Peak Hill.
Peelwood.
Perico, near Eden.
Picton, near.
Pindari, Parish of, County of Arawatta.
Pine Ridge, near Inverell.
Plant Gully, near Emmaville.
Pool's Corner, near Winburndale.
Port Macquarie.
Pretty Gully.
Pudman's Creek (Rye Park).
Purnamoota.
Pye's Creek.
Queanbeyan District.
Quedong.
Red Range, New England.
Red Rock, Drake.
Reedy Creek.
Restdown, Nyngan.
Rivertree.
Rockley (Back Creek).
Rockvale, twenty-four miles from Armidale.
Rockwell Paddock, Broken Hill.
Rocky Hall.
Rosedale.
Rye Park.
Rylstone, ten miles from.
Scone, six miles from.
Severn River.
Sewell's Creek.
Sherwood, Macleay River.
Shoalhaven River.
Silverton.
Singleton, near.
Snowy River.
Solferino.
Spicer's Creek.
Spring Creek, Bungonia.
Springside.
Staggy Creek, Inverell.
Stanborough.
Stony Batta, New England.
Strathbogie, two miles north of.
Sunny Corner.
Swanbrook, Parish of, County of Gough.
Tait's Gully.
Talbragar.
Tambar Springs.
Tarago.
Tarana.
Tarrabandra.
Tavistock (Blatherarm Creek).
Temora.
Ten Mile.
Tent Hill.
Tenterfield.
Teralga (Mount Werong).
Thackeringa.
The Peaks, Burragorang.
Thirlmere.
Tilbuster Creek.
Tilga Mountain.
Timor.
Tinda Mountain.
Tindary.
Tingha.
Tooloom, near Pretty Gully.
Trunkey.
Tuena (Sunny Ridge).
Turlinjah, near Moruya.
Turon Ranges.
Umberumberka.
Upper Burragorang.
Uralla, seven miles west of.
Uriana.
Uriaria.
Vegetable Creek.
Walcha and Bendemeer, between.
Wallangra, near.
Walla Walla Mines, Rye Park.
Warneton.
Warrell Creek.
Waverley, New England.
Weddin Mountains.
Wee Jasper.
Wellington.
Wellington Vale, New England.
Whipstick, near Panbula.
Wilcannia, near.
Willie Willie, Macleay River.
Willow Rush, near.
Windellama.
Wiseman's Creek.
Wog Wog, near.
Wongobah.
Wollomombi River, Armidale district.
Wolumla.
Wooloomon.
Wyagdon.
Wyndham.
Yalgogrin.
Yalwal.
Yarrahapinni.
Yarrangobilly.
Yarrowford.
Yass.
Yeoval.
Young.
Yowaka.

*Production of Silver, Silver-lead, and Ore.*

Quantity and Value of Silver, and Silver-lead, and Ore exported.

| Year. | Silver. | | Silver-lead and Ore. | | | Total Value. |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | Quantity. | | Value. | |
| | | | Ore. | Silver-lead. | | |
| | oz. | £ | tons cwt. qr. | tons cwt. | £ | £ |
| 1881... | 726,779·14 | 178,405 | 191 13 0 | ........... | 5,025 | 183,430 |
| 1882... | 38,618·00 | 9,024 | 11 19 0 | ........... | 360 | 9,384 |
| 1883... | 77,065·90 | 16,488 | 105 17 0 | ........... | 1,625 | 18,113 |
| 1884... | 93,660·25 | 19,780 | 4,668 1 0 | ........... | 123,174 | 142,954 |
| 1885... | 794,173·80 | 159,187 | 2,095 16 0 | 190 8 | 107,626 | 266,813 |
| 1886... | 1,015,433·10 | 197,544 | 4,802 2 0 | ........... | 294,485 | 492,029 |
| 1887... | 177,307·75 | 32,458 | 12,529 3 2 | ........... | 541,952 | 574,410 |
| 1888... | 375,063·70 | 66,668 | 11,739 7 0 | 18,102 5 | 1,075,737 | 1,142,405 |
| 1889... | 416,895·35 | 72,001 | 46,965 9 0 | 34,579 17 | 1,899,197 | 1,971,198 |
| 1890 .. | 496,552·80 | 95,410 | 89,719 15 0 | 41,319 18 | 2,667,144 | 2,762,554 |
| 1891... | 729,590·05 | 134,850 | 92,383 11 0 | 55,396 3 | 3,484,739 | 3,619,589 |
| 1892... | 350,661·50 | 56,884 | 87,504 15 0 | 45,850 4 | 2,420,952 | 2,477,836 |
| 1893... | 531,972·00 | 78,131 | 155,859 1 0 | 58,401 3 | 2,953,589 | 3,031,720 |
| 1894... | 846,822·00 | 94,150 | 137,813 8 0 | 42,513 2 | 2,195,339 | 2,289,489 |
| 1895.. | 550,142·00 | 81,858 | 190,192 19 0 | 29,687 7 | 1,560,813 | 1,642,671 |
| 1896.. | 202,789·00 | 26,518 | 267,363 1 0 | 19,573 4 | 1,758,933 | 1,785,451 |
| 1897... | 150,005·00 | 16,711 | 270,913 14 0 | 18,105 7 | 1,681,528 | 1,698,239 |
| 1898... | 533,059·00 | 59,278 | 388,460 4 0 | 10,108 13 | 1,644,777 | 1,704,055 |
| 1899... | 692,036·00 | 76,913 | 424,337 5 0 | 20,289 10* | 1,993,744 | 2,070,657 |
| Totals | 8,798,626·34 | 1,472,258 | 2,187,657 0 2 | 394,117 1 | 26,410,739 | 27,882,997 |

Note.—The bulk of the silver produced in New South Wales is exported in the form of silver-lead.

* Includes 32 tons of silver-sulphide, valued at £20,317.

# TIN.

The late Revd. W. B. Clarke was the first to foretell the probable occurrence of tin in New South Wales, as well as the first to actually discover the ore.

In a leading article, written by Mr. Clarke, in the *Sydney Morning Herald*, of the 16th August, 1849, the following passages occur :—

" And here, merely for the sake of usefulness, we suggest that though tin has not yet been found in this Colony, it may hereafter be discovered. It is not improbable that it will be found along parts of the Murrumbidgee, where granite occurs with abundance of *Schorl;* since in granitic districts of Cornwall, oxide of tin has a marked connection with schorl, which latter mineral is a principal ingredient in the tin lodes. The writer of this suspects, however, that he has found crystals of tin in granite from the locality mentioned, though he did not pay particular attention to the fact. The abundance of copper in this Colony would naturally suggest the probable occurrence of tin; though it is equally probable that the abundance of our copper is mainly due, not to the existence of true granites, but to the occurrence of trap rocks of the more useful varieties."

In view of the subsequent discovery of large deposits of tin oxide in this Colony, the foregoing must be regarded as a remarkable instance of successful deductive reasoning.

The same writer, in a report (dated 24th December, 1851), dealing with the geology of the country in the neighbourhood of Kosciusco, makes the following remarks :—" In some places the granite becomes porphyritic, entangling segregated lumps of finer texture, and containing patches of eurite, leptynite, and *tourmaline pegmatite*, with some quartz veins. The action of the snow has removed the softer materials from the surface, and the quartz, therefore, remains exposed, and, thus exhibited, shows a peculiar disposition in regular lines. The tourmaline places the granite not far from that of Dartmoor, and *one might expect tin in the vicinity. I obtained. one small specimen from the granite.* None was, however, found amidst the detritus."

In another report (dated 7th May, 1853), on the geological structure of the western slopes of the Highlands of New England, Mr. Clarke again records the discovery of tin. He says :—" Wolfram and oxide of tin, with tourmaline, occur near Dundee, and in Paradise Creek, and it is probable that this ore of tin is plentifully distributed in the alluvia of other tracts, as I have found it amidst the spinelle rubies, oriental emeralds, sapphires, and other gems of the detritus from granite." He also states that in New England he found oxide of tin in the form of crystals of felspar.

Five months later (14th October, 1853), in a report describing the geology of a district (the Darling Downs) which now forms part of Southern Queensland, Mr. Clarke writes as follows :—" I may, however, here remark that though gold be wanting, there are gems and tin ore in many localities, of which little account was taken, but which may, perhaps, be one day as valuable as gold. Respecting the tin ore, I may state that I found it in almost every mass of drift in every portion of the country I have explored for gold, and that it is frequently abundant where gold is wanting. It exists in all the western streams, from the Peel to the Condamine, and it was equally common in the southern districts."

In his " Geology of the Vegetable Creek Tin-mining Field," Professor David says :—" Little or no notice appears to have been taken of this important discovery of tin by Mr. Clarke in 1853. In 1860, however, a considerable quantity of stream tin, obtained from the alluvials at Oban, in the same district, was purchased as such by Lassetter and Co. . . . In the beginning of 1872 public interest in New South Wales was aroused by the accidental discovery of tinstone, by the Messrs. Fearby, at Elsmore, near Inverell. Mr. Cleghorn, of Uralla, had sent the Messrs. Fearby to prospect the creeks of this district for gem-stones, the best localities for which were pointed out to them by an old shepherd on Newstead Station, named Wells. Mixed with a number of sapphires and other gems, in the gravels of the creeks, was a heavy black mineral, in water-worn grains, which the Messrs. Fearby, supposing to be tinstone, sent to Sydney to be assayed for tin. The result of the assay proved that this black mineral was oxide of tin, and, the discovery becoming known, Baron and Moxham, and other capitalists, took up the ground near the present Elsmore Mine. Then commenced the rush to the New England Tin-fields. The stream tin under the title of " black sand " had been long familiar to gold-miners in New England, at Oban, and elsewhere, where its weight, rendering it difficult of removal from the sluice-boxes, had caused it to be regarded as worse than a nuisance; and at Captain Swinton's station, near Tingha, I was informed that his stockmen were in the habit of using the stream tin of Cope's Creek for cleaning their bits. As knowledge of its value spread, eager prospecting led to its presence being proved over wide areas—areas which have been constantly extended since this discovery of tin at Elsmore, in 1872, until the latest finding of tin at Gumble, near Molong, in 1885. . . . Vegetable Creek is only 34 miles distant, in a direct line north-north-east from Elsmore, so that at the time when prospecting for tin was being so vigorously prosecuted in its neighbourhood, it was impossible for such a rich stanniferous area to remain long unknown; and in March, 1872, Thomas Carlean first discovered stream tin here, near the source of Vegetable Creek."

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box sluicing in the early days of the field, and a certain number of Chinese have obtained a living by reworking portions of it for many years past. The operations of the company will be watched with interest, as this will be the first attempt to recover tin-ore by this method of mining.

Middle Creek, which is four or five miles to the north of Cope's Creek, and flows into the McIntyre River, was also extensively worked for alluvial deposits of tinstone.

Sandy Creek, to the south of Cope's Creek, flows into the Gwydir River. Some tin-ore is said to have been obtained from this creek near its mouth, but all attempts to prospect its bed for a considerable distance below its source were ineffectual owing to the presence of strong bodies of water in the sands. It is probable that dredging would be an effective method of overcoming this difficulty, and as this creek drains similar country to that traversed by Middle Creek, and Cope's Creek, there appear to be fair grounds for believing that profitable returns would be obtained. It would not be a very costly matter, however, to prospect the wet ground, and this should be done before the expense of constructing a dredge is incurred.

At Emmaville, where tin-mining was commenced very soon after the opening of the mines in the Inverell District, the most productive Post-Tertiary deposit was that known as the Vegetable Creek *lead.**

Between the years 1872 and 1884, 15,000 tons of cassiterite are said to have been extracted from this shallow alluvial deposit, within a distance of a little over five miles from its source downwards. The alluvials varied from two to fifteen chains in width, and the portions richest in stream-tin were from one to five chains wide. The average thickness of the payable tin-bearing wash was two feet six inches. The alluvials comprised loose deposits of sand, gravel, and rubble, with hard sheets of cement or natural tin-bearing concrete, extending back for several chains from the banks of the creek. The total area of ground worked was about 150 acres, which produced 15,000 tons of stream tin, or at the average rate of 100 tons per acre, or half a hundredweight of cassiterite per cubic yard, allowing the mean depth of the washdirt to be two feet six inches. The depth of stripping varied from six inches to nine feet.

At Catarrh Creek about 1,000 tons of stream tin were obtained from the shallow alluvials within a distance of about one mile. The width of the deposit varied from three to seven chains, and the depth of sinking to the granite bed rock was from ten to fourteen feet. The tinstone was mostly black, but occasionally ruby tin and resin tin were also obtained. The grains were very much waterworn, and their average diameter was one-twentieth of an inch.

Shallow alluvial deposits of Post-Tertiary age have been worked for tin in no less than twenty-seven localities in the Emmaville District, with

* Much of the following information in regard to the Emmaville tin deposits has been obtained from Professor David's memoir on the "Geology of the Vegetable Creek Tin-mining Field."

*Photographed by E. F. Pittman.*

TIN-SLUICING IN THE OLD VEGETABLE CREEK LEAD, EMMAVILLE.

*Photographed by E. F. Pittman.*

THE ELSMORE VALLEY TIN MINING COMPANY NEAR INVERELL.

more or less successful results. In the Parish of Muir, masses, or nuggets, of black tin-ore were found close to the surface; the largest of these weighed thirty-two pounds.

*Tertiary alluvial deposits* (*Deep Leads*).—The tin-bearing greisen, the disintegration of which produced the rich surface deposits of tinstone, already alluded to, at Elsmore and Newstead, was also undergoing decomposition during early Tertiary times, and as a consequence of this, large quantities of stream-tin were deposited in the valleys which received the drainage of this country during the Eocene period. The stanniferous deposits were covered with a considerable thickness of alluvium, consisting of gravel, sand, and clay, and containing leaves, nuts, branches of trees, and large logs, all of which are now preserved in a fossilised state. Eventually the valleys were invaded by streams of molten lava, so that they have since been protected from denudation by a considerable thickness of basalt.

The country intersected by these deep *leads* consists of hard bluish-gray claystones of Carboniferous age, and areas of intrusive granite and greisen. There are also numerous intrusive dykes of eurite, diorite, and basalt. Frequently on the higher ground are found deposits of older Tertiary volcanic ash, which now consist essentially of the mineral bauxite.

*The Elsmore Valley Lead*, about ten miles south-east of Inverell, was, in the first instance, prospected by a bore. At a depth of 187 feet a bed of washdirt, 10 feet 6 inches in thickness, and estimated to yield 15 lb. of stream-tin per load, was intersected. At a depth of 201 feet 6 inches another bed of washdirt, 18 inches thick, and containing at the rate of 100 lb. of stream-tin per load, was met with, and two feet below this was a third deposit of washdirt one foot thick. This *lead* is now being worked by the Elsmore Valley Tin-mining Company, whose main shaft is 225 feet deep. The mine labours under the disadvantage of having a very limited working capital, and could probably do much better if worked on a more extensive scale. The deposits of stanniferous washdirt are found to vary considerably in thickness, and occasionally the two lower beds, intersected in the bore, unite, while in other places they are separated by several feet thick of sand and clay. The yield of tin is also variable, but it is stated that the average contents are about 100 lb. of tin per load, and the mean thickness of washdirt is about 2 feet 6 inches. The tinstone is said to be of good quality, assaying from 76 to 77 per cent. of metallic tin when cleaned, and contains only a trace of wolfram.

The only mine opened on this *lead* is that of the Elsmore Valley Tin-mining Company, and comparatively little work has been done there, so that very little is known as to the extent of the deposit, and in view of the recent advance in the price of tin, there is plenty of room for further development.

*The Newstead Lead.*—This *lead* was traced from surface deposits of tin-ore on the slope of a greisen range, and was found to deepen gradually as it was worked northwards, until, at the spot where it passes under Newstead Creek, Cody's shaft had a depth of seventy feet, and some hundreds of tons of tin-ore were extracted from this claim. The Newstead Company put down two shafts north of Cody's claim, and very rich deposits were worked from the first, which had a depth of 130 feet. Eighteen tons of clean ore were obtained from one drive, but no blocking out was done. One load is said to have yielded 360 lbs. of ore, but the bottom was found to dip so rapidly that a second shaft was sunk to a depth of 190 feet, in solid granite, on the bank of the creek, and a drive was put in under the creek. About this time mining operations were stopped on account of want of capital. The *lead* is said to have an average width of 140 feet. There is every reason to believe, especially in view of the enhanced value of tin, that there are payable deposits of ore here, which only require capital for their development. There is a number of other Tertiary tin-bearing *leads* in the Inverell district, such as *The Donegal Lead, Dick Jones' Lead, Brickwood's Lead, M'Millan's Lead, Standard Lead, Jealousy Lead, Walmsley's Lead, The United Lead,* &c.

Near the junction of Cope's Creek with the Gwydir River are several isolated basalt capped hills marking the course of an old Tertiary river-bed which once flowed approximately parallel with the Gwydir. Under the basalt is a considerable deposit, fourteen feet thick in places, of well water-worn quartz pebbles, with large boulders of decomposed granite. This alluvial drift rests on a granite bottom, and is at the present time being worked for diamonds, which occur in considerable quantities, but of small size. The diamonds are accompanied by topaz, sapphire, zircon, tourmaline, ilmenite, magnetite, spinel, pleonaste, &c., and the washdirt contains, in addition, up to as much as 15 lbs. of stream tin per load. Although the tin is not, therefore, in sufficient quantity to render its extraction, *per se*, profitable, it forms a by-product, the value of which goes a considerable way towards covering the cost of extracting the diamonds. The gems just enumerated are also found associated with the stream tin in Cope's Creek, and many of the other watercourses in which stanniferous deposits have been worked in the Inverell District. With the exception of the diamond, however, none of them is of any commercial value.

In the Emmaville or Vegetable Creek District the Tertiary alluvial deposits have been divided into two classes, viz. (*a*) those which are capped by lava; and (*b*) bare deposits, or those from which the cap of lava has been removed by denudation. Examples of the latter class occur at Scrubby Gully, Surface Hill, Ruby Hill, and Y Water-holes. The deposit at the Y Water-holes is by far the most important of this class. It has an area of about 1,100 acres, and its depth averages about twenty feet. The alluvial deposits of clay and sand show characteristic current bedding. The ore is richest at the base of the beds, while the surface dsposits contain more stream tin than the intermediate beds, owing to their having received the ore from the sluicing of a considerable thickness of sands which at one time overlay them, but which have since been removed by denudation. There is no evidence of the concentration of ore in old channels in this deposit, and it is, therefore, probably of lacustrine origin.

The following are the principal basalt-capped Tertiary *leads* which have been worked for tin in the Emmaville district :—

1. *The Vegetable Creek Lead*, including the basaltic country to "Kangaroo Flat," "Hall's Sugarloaf," "Paddy's Sugarloaf," and "The Surprise."
2. *The Graveyard Lead.*
3. *The Springs Lead.*
4. *Rocky Creek Lead.*
5. *Ruby Hill Lead.*
6. *Wellington Vale Lead.*

Of these, the Vegetable Creek Lead has proved to be by far the most important, and there can be no doubt that in early Tertiary times it formed the main drainage channel of this country. In portions of its course there were two distinct flows of lava, an older and a newer, each covering a bed of stanniferous washdirt. Up to the year 1886 the produce of these latter was 6,000 tons of stream tin in a distance of 2 miles 30 chains. At one place an area of 5½ acres of gravel, having an average thickness of three feet, yielded 2,000 tons of tin-ore. The main direction of the lead was west, and its width varied from a few feet up to, in one instance, as much as 400 feet. The thickness of the deposit of washdirt was occasionally as much as fourteen feet; but its average was about three feet. Blank spaces were occasionally found in the lead, where the fall of the old river-bed was steepest, owing to the tin-ore having been washed down to where the bottom was more level.

*The Vegetable Creek Lead* had two main feeders or tributaries, viz., the old *Rose Valley Lead* and *Fox's Deep Lead.*

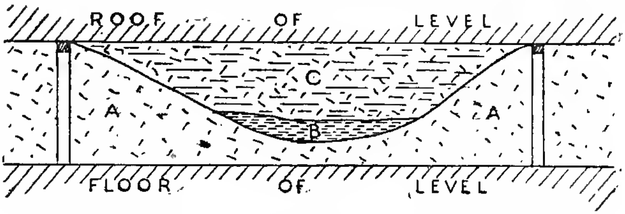
The *Graveyard Lead* is south of, and approximately parallel with, the *Vegetable Creek Lead*, and the two *leads* probably junction about six miles west of Emmaville. A considerable amount of basalt-covered country runs from this point in a northerly direction through Kangaroo Flat to Avoca and the Fishing Grounds, and, as stanniferous drift has been worked at these places, at a sufficiently low level to allow for the average fall of the old river valley, it is probable that the main *lead* will ultimately be proved for a distance of at least fifteen miles, though it is scarcely probable that the tin-bearing washdirt will be found to be continuous; on the contrary, it is much more likely that stretches of unproductive alluvial deposits will be encountered, where the old river has intersected country which is not tin-bearing. Still, there is every reason to believe that considerable areas of unproved payable deposits exist, and these offer a fair opportunity for the investment of capital.

The greatest depth from the surface at which a *deep lead* in the Emmaville District has been worked is about 250 feet. In Wesley Brothers' mine, at the junction of *Fox's Deep Lead* and the *Vegetable Creek Lead*, the shaft, after passing through several distinct flows of basalt, penetrated a layer of gravel at 247½ feet from the surface. This gravel also rested on an eroded surface of basalt, so that there is a possibility of another alluvial gutter occurring at a still greater depth.

*The Wellington Vale Lead.*—The head of this old Tertiary alluvial deposit is situated at a locality known as The Nine Mile, to the north-west of Deepwater. Rich shallow deposits of stream tin have been worked here along a flat trending from the south-eastern slope of Battery Mountain; but after being followed to the east and north-east for about a mile, they were found to dip below the basalt, a narrow strip of which extends southwards for some miles, forming a covering to the *Wellington Vale Lead.* No shaft has ever been bottomed in this alluvial deposit under the basalt, although a number of attempts has been made to prospect it. The cause of failure in each instance has been the quantity of water met with, which has been too great for the resources of small parties of miners, and it is evident that the work can only be successfully carried out by a company possessed of sufficient capital to provide the necessary pumping machinery. In view of the richness of the shallow deposits forming the head of the *lead*, there is good reason for expecting that the gravels, in the channel now covered by basalt, will prove payable, and, with the object of practically testing the question, the Government have recently granted aid from the Prospecting Vote to sink a shaft through the basalt. The experiment will be watched with much interest, as, if successful, it will probably result in the opening up of a considerable length of deep alluvial ground, besides giving encouragement for the prospecting of other basalt covered *leads* in the Emmaville District.

The geology of Emmaville is, in most respects, very similar to that of the country round Inverell. The oldest sedimentary rocks are the bluish-gray clay-stones of the Carboniferous period, and these have been intruded by tin-bearing granites, and by quartz felsites and diorites. There was a great amount of volcanic activity during Tertiary times, as is attested by the sheets of lava, and deposits of volcanic ashes. These latter occupy an area of nearly twelve square miles, and they vary in thickness from a few feet up to 40 feet. The beds consist at the surface of a red dusty soil, and pass downwards into red, yellow, or gray tuffs, and compact pisolitic rock containing a variable percentage of alumina and peroxide of iron; these in their turn graduate into rotten spongy basalt. These ash deposits consist essentially of the mineral bauxite, and will doubtless be of considerable value in the future for the manufacture of the metal aluminium.

At Bailey's Mine, Rose Valley, there is an extremely interesting occurrence of a stanniferous alluvial *lead* overlaid by a felspar-porphyry lava. This occurrence was first recorded by Mr. S. H. Cox, A.R.S.M., and is the only known instance in Australia of a *lead* covered by an acidic lava. (Journ. R. Soc. N.S.W., Vol. XX, 1886, p. 105).




A. Felspar porphyry. B. Tin wash. C. Felspar porphyry.

SECTION ALONG PROSPECTING DRIVE IN BAILEY'S MINE.
(After S. H. Cox.)

Bailey's Mine is situated on the junction of intrusive felspar porphyry with the Carboniferous claystones, and the floor of the *lead* is formed sometimes of the one rock and sometimes of the other, in different parts of the mine. It is probable that the acidic lava covering the wash-dirt was nearly contemporaneous with the basalts which are found overlying the other deep *leads* in the district, and represented the earlier products of the volcanic eruptions.

*Associated Minerals.*—The following minerals are found associated with the stream-tin in the Emmaville deep *leads*, viz.:—Magnetite, ilmenite or titaniferous iron, tourmaline, spinel (pleonaste), quartz, topaz, zircon, sapphire, and beryl (emerald).

*Tin-bearing Lodes.*—The stanniferous lodes in the Inverell and Emmaville Districts comprise (*a*) Fissure Veins, (*b*) Joint Veins, or those following joints in the granite or felspar porphyry, and (*c*) Pipe Veins. The veins are found most frequently in the granite, and they occur almost exclusively within a distance of about a mile and a half of the junction between the granite and the claystones. Professor David states that, in the Emmaville District—

76 veins are enclosed in granite.
8 ,, ,, ,, quartz porphyry.
3 ,, ,, ,, porphyroid.
3 ,, ,, ,, claystone.

He also noted that out of seventy-seven veins in this district, in which tinstone occurs, nineteen consist of quartz and tinstone only, and eight of felspar and tinstone only; also that sixty-nine veins contained quartz, twenty-nine contained chlorite, and twenty contained felspar. The following minerals also occur in different veins in the district, viz., mica, mispickel, iron pyrites, fluorspar, tourmaline, wolfram, zincblende, galena, copper pyrites, bismuth, molybdenite, vesuvianite, stilbite, hematite, pyrrhotine, manganese, scheelite, and beryl.

*Strike of Lodes.*—The average strike of fifty-four right running veins was found to be N. 39° 15′ E., the range of strike being from N. 24° E. to E. 20° N.

*Dip.*—The average dip of thirty-seven veins observed was 77°.

33 veins dip north-westerly.
10 ,, ,, south-westerly.
3 ,, are vertical.

Those veins, or portions of veins, which most nearly approach the vertical have, so far, proved the richest.

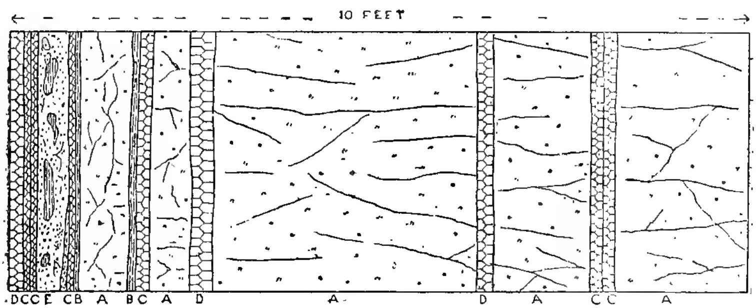
*Length.*—The greatest length for which a vein has been proved to be tin-bearing is about one mile.

*Width.*—The average width of sixty-nine veins is 1 foot $6\frac{3}{4}$ inches. The six largest veins hitherto worked have the following thicknesses, viz. :—

| | | |
|---|---|---|
| No. 1. | Ottery vein ... ... ... | 3 feet. |
| No. 2. | ,, ,, ... ... ... | 4 ,, |
| | Butler's vein ... ... ... | 3 feet 2 inches. |
| No. 1. | Dutchmans vein ... ... | 4 ,, |
| No. 2. | ,, ,, ... ... | 3 ,, |
| | Curnow's vein ... ... ... | 3 ,, |

The majority of the other veins are narrow.

The ore in most of the stanniferous veins occurs in *chutes*, which are inclined more or less steeply from the horizontal, and obliquely along the plane of the lode. The average length of the six largest *chutes*




Section showing character of Butler's Vein, Emmaville District.
(After T. W. E. David.)

observed was 100 feet; average width $1\frac{1}{2}$ feet; average depth 6 feet; average dip 26°; average horizontal distance between *chutes*, about 80 yards; vertical distance between *chutes*, 50–90 feet. Eleven *chutes* were observed to dip north-easterly; two *chutes* were observed to dip south-westerly.*

* T. W. E. David—"The Geology of the Vegetable Creek Tin-mining Field."

*Stanniferous pipe veins* are a peculiar feature of both the Emmaville and Inverell Districts. They occur in granite, as a rule, and are cylindrical or oval in form. They sometimes dip at a considerable angle, at other times their course downwards is vertical. They do not often extend to any considerable depth, thinning out at about thirty or forty feet. They are occasionally as much as four or five feet in diameter, and within these limits the tinstone occurs disseminated through a gangue of felspar, quartz, and chlorite. Several of these pipes, or "shoots" as they are termed by the miners, are at the present time being worked in the vicinity of the Nine Mile; they are all very similar in their mode of occurrence, the chief difference being in the diameter of the deposit. The following particulars of one of them may be quoted. Messrs. Crockett and Knight's tin-bearing pipe vein is situated in granite country on the bank of the Bark Hut Creek, about twelve miles north-west of Deepwater. Where originally found the pipe vein was nearly horizontal and had a southerly trend; it was about three feet in diameter, and in a distance of a few feet it yielded eight tons of tinstone, when it thinned out to an inch or two in diameter, and was abandoned. Subsequently, when tin had risen to a better price, the present owners started to re-open the deposit, and soon found that it increased in diameter and assumed a vertical course. It was followed down for about fifteen feet, having a diameter of about two feet six inches, and then gradually became horizontal again. The excavation now measures about forty feet from the surface, and the deposit has forked or divided into two pipe veins, each of which is about nine inches in diameter. The proprietors have taken out about four tons of tinstone since re-opening the deposit, so that the total yield has been twelve tons up to the present. The gangue consists of green felspar, and crystals of cassiterite thickly disseminated through this. The average yield of the ore is ten hundredweight of tinstone per ton, and the tinstone contains from 75 to 76 per cent. of metallic tin.

*Stockworks.*—Minute veins of tinstone occur in quartz porphyry or felstone in many places in the Emmaville District, forming what are known as stockworks. The minute veins appear, in many cases, to follow joints, which cross one another in several directions in this intrusive rock. They have not, so far, proved payable to any considerable extent.

*Impregnations.*—Allusion has already been made to impregnations of tinstone in greisen at Elsmore and Newstead, in the Inverell District. At Pheasants Creek, to the east of Glen Innes, some extremely rich deposits of tin-greisen have been found, but these were limited in extent. Impregnations of tin-ore are also found alongside joints in the granite in the Emmaville District, and the pipe veins already described might also be considered to belong to this class of deposit.

*The Ottery Tin-lodes.*—These lodes are situated about two miles to the north of the village of Tent Hill. There are, at least, five distinct lodes, and they occur intersecting dykes of hornblendic granite and eurite, within a distance of a few chains from the junction line of these intrusive dykes with the Carboniferous claystones. The lodes strike north-east and north, and their dip is towards the north-west and west, at angles varying from 30° to 80°. One of these is the only stanniferous lode at present being worked in the vicinity of Emmaville, though others are being worked by small parties of miners in the neighbourhood of Torrington and The Nine Mile. As mining operations have been carried on in connection with the Ottery lode for more than sixteen years, a brief description of the deposit may not be out of place.

The outcrops of all the Ottery lodes consist of ferruginous gossany quartz containing tinstone, and may be traced on the surface for a considerable distance in a south-westerly direction towards the head of the old (Pleistocene) *Vegetable Creek Lead*, and there can be very little doubt, therefore, that the extremely rich deposits of stream tin, which were recovered from those shallow alluvials, were derived from the denudation of portions of the Ottery lodes, and from stockworks occurring along their line of strike.

The oxidised or gossanous portion of the lodes extends to a depth of from forty-five to seventy-five feet, and in the worked-out portions of the mine the walls of the shafts and drives, within this zone, are quite green with an efflorescence consisting of sulphate and arseniate of iron. Below the zone of oxidation, the ore passes into compact mispickel and quartz, containing tinstone. In some places the lodes are characteristically banded; in others the mispickel is quite massive. The main lode has been worked at the surface for a length of about 1,000 feet, and, at the 230-feet level, it has been worked for a length of about 750 feet. In two places the upper portions of the lode have been removed by open cuts, and there are also three shafts, the two deepest of which are 300 and 350 feet respectively, measured on the underlie. On the top of the hill, near the most southerly shaft, a lump of tinstone was found, weighing 2 cwt. 1 qr. 24 lb., and assaying at the rate of 72 per cent. of metallic tin. At a depth of fifty feet from the surface, a shoot of ore was met with which dipped northerly at an angle of about 20°. This shoot was ninety yards long, five yards high, and varied from four inches to one foot in width; it consisted of nearly solid tinstone. In the upper workings of the mine the more highly inclined portions of the lode were found to be richer in tin than those portions in which the dip was slight or moderate. At a depth of seventy feet, in the middle (or deepest) shaft, the lode was split by a "horse" of granite, which continues to the 300-feet level. The two portions into which the lode is thus divided are known respectively as the foot wall lode and the hanging wall lode. They vary in width from six inches to four or five feet, and are usually banded in character. The "horse" is tin bearing, but is usually of low grade. The maximum width of the mineralised formation, including the two lodes and the "horse," is thirty feet. In

*Photographed by E. F. Pittman.*

THE OTTERY TIN MINES NEAR TENT HILL EMMAVILLE DISTRICT.

places the horse has all the character of a stockwork, consisting of a matrix of hornstone and quartz, intersected by minute veins of quartz showing tinstone and arsenical pyrites. Occasionally the full width of the formation has been extracted for a width of more than 25 feet, and some remarkable timbering is to be seen, consisting of stull pieces, having a length of as much as twenty-seven feet six inches. The presence of considerable quantities of arsenical salts in the mine-water appears to have a wonderful effect in preserving the timbers, and dry rot is apparently unknown here. In the upper levels the lode was characterised by clean and well-marked walls, showing slickensides, but in the lower portions of the mine there are seldom any signs of defined walls, and the country outside the hanging wall and foot wall lodes is as much mineralised as the "horse" which separates them. Occasionally specks of copper pyrites and small crystals of galena and zincblende are seen in the lodes, but these minerals never occur in any quantity.

The ore raised from the lower levels of the mine has for some considerable time past yielded less than 3 per cent. of tinstone, so that it is essentially a low-grade as well as a refractory ore.

The lode has, for the most part, been worked by underhand stoping, the workings keeping pace with the excavation of the shafts. This is, for many reasons, an unsatisfactory method of exploiting, but its adoption is probably due to the continued low grade of the ore, and the consequent disinclination of the owners to incur the expense of sinking the shafts to a sufficient depth below the working faces, to allow of the subsequent removal of the ore by overhand or back stoping. As, however, the mine has been able to pay its way when tin was at an extremely low price, it is probable that much better returns could be obtained if a more vigorous policy were adopted, more especially in view of the present satisfactory price of the metal.

*Local Treatment of the Ore.*—The Glen Tin Smelting Works were established at Tent Hill when the Ottery lodes were first opened, but smelting operations ceased about five years ago. At the present time the ore is calcined and concentrated locally, and the tin-oxide is then forwarded by teams to Deepwater (14 miles), and thence by rail to Sydney, where it is smelted.

The ore is first roasted in heaps at the mine to get rid of the greater part of the arsenic. It burns freely, as it contains a very large proportion of mispickel, and the heaps generally burn out in about a fortnight or three weeks. This preliminary roasting costs about 9d. per ton. The roasted ore is then carted, at a cost of 1s. 9d. per ton, to the concentrating works at Tent Hill, where it is crushed in a battery of fifteen stamps. The pulp from the battery passes through two hydraulic classifiers, and the graded material is conveyed thence to four Frue vanners. The heavier product from No. 1 classifier goes to No. 1 vanner, while the overflow from this classifier goes into No. 2 classifier; the overflow from here goes to No. 4 vanner, and the heavier material is fed on to vanners numbers 2 and 3. The Frue vanners separate the first concentrates from the tailings; the latter, consisting chiefly of quartz, are discarded, while the concentrates are next treated on convex buddles, which further separate them into "heads" and "tails." The heads are then thoroughly roasted in a reverberatory calcining furnace, after which they are again concentrated on a convex buddle. The "heads" from this process are now treated in a tossing tub, and the final concentrates thus produced are thrown into a heated oven, and, after being dried, are forwarded to the smelting works in Sydney.

The entire plant consists of fifteen head of stamps, two hydraulic separators, four Frue vanners, four 18-ft. convex buddles, two tossing tubs, a calcining furnace, 18 ft. x 9 ft., and a drying oven. The ore, after treatment, contains about 70 per cent. of metallic tin, and the output is from twelve to eighteen tons of clean ore per month.

*Other Lodes at the Ottery Mine.*—There are several other parallel lodes at the Ottery Mine which have, as yet, been scarcely prospected; one of these is situated about fifty feet to the east of the lode now being worked, while another, which, judging by its strong outcrop, would appear to be much the largest deposit in the district, is situated about 200 feet still further to the east. There is every reason to believe, therefore, that very extensive deposits of lode tin exists in this neighbourhood, though the mining operations hitherto carried out show that much of the ore is of low grade. However, if ore containing less than three per cent. of tin could be made to yield a margin of profit in spite of the low price of the metal which has ruled for some years past, the future should surely be hopeful in view of the largely increased price now obtainable.

Comparative statement of the amount of tinstone produced in the Inverell and Tingha, and the Emmaville Districts respectively from 1872 to the end of 1898 :—

| Year. | Inverell and Tingha District | Emmaville District. | Year. | Inverell and Tingha District. | Emmaville District. |
|---|---|---|---|---|---|
| | tons. | tons. | | | |
| 1872-3 ... | not recorded. | 2,592 | 1888 ... | 1,007 | 1,037 |
| 1874 .. ... | ,, | 2,249 | 1889 ... | 1,352 | 1,553 |
| 1875... ... | 1,674 | 3,042½ | 1890 ... | 1,000 | 1,150 |
| 1876... ... | 2,300 | 3,008⅔ | 1891 ... | 862 | 973 |
| 1877... ... | 1,800 | 1,749 | 1892 ... | 600 | 1,063 |
| 1878... ... | 1,107 | 1,935¾ | 1893 ... | 700 | 1,035 |
| 1879... ... | 1,035 | 2,715⅓ | 1894 ... | 742 | 871 |
| 1880... ... | 1,722 | 3,960 | 1895 ... | 470 | 649 |
| 1881... ... | 2,500 | 4,539½ | 1896 ... | 500 | 723 |
| 1882.. .. | 3,110½ | 3,517 | 1897 ... | 402 | 600 |
| 1883... ... | 3,636 | 2,509 | 1898 .. | 400 | 478 |
| 1884... ... | 2,392 | 2,241 | 1899 ... | 539 | 529 |
| 1885... ... | 1,834 | 2,505¼ | | | |
| 1886... ... | 1,649 | 1,894 | Total ... | 34,593½ | 51,758 |
| 1887... .. | 1,260 | 2,639 | | | |

*The Jingellic Tin Lodes.*—On the southern border of New South Wales tin occurs in lodes at Jingellic, about sixty miles to the east of Albury. Here again the mineral is found under the same geological conditions which mark its occurrence in the northern fields—that is to say, the deposits occur in granite, close to its junction with slate rocks.

The lodes at Jingellic are situated principally in a high granite range extending along the northern bank of the Murray River, at the head of Swamp Creek. A flat, about a mile in length, extends from the bank of the Murray up to the foot of the range, and here the Swamp Creek forks, the western branch being known as Little Swamp Creek. A company, known as the Jingellic Tin-mining Company, formerly held about four hundred acres here, a considerable portion of it being freehold land, and they also held the right to mine for stream-tin on the flat; much of their capital was, however, expended in unproductive work, and they suspended operations about eighteen years ago, although very little actual prospecting of the lodes had been done.

In the ranges above the flat no less than eight well-defined quartz lodes occur, all carrying tin in greater or less quantity. No. 1 lode on the range is situated at an elevation of about nine hundred feet above the river. It strikes east and west, and is almost vertical, having a slight dip to the north. A tunnel was put in along the course of this lode for a distance of one hundred and sixty feet, and a winze was sunk for a depth of thirty feet. The lode was found to vary in width from ten inches to two feet, and the quartz, in places, contains a large amount of tourmaline, with some wolfram, and a fair sprinkling of tinstone.

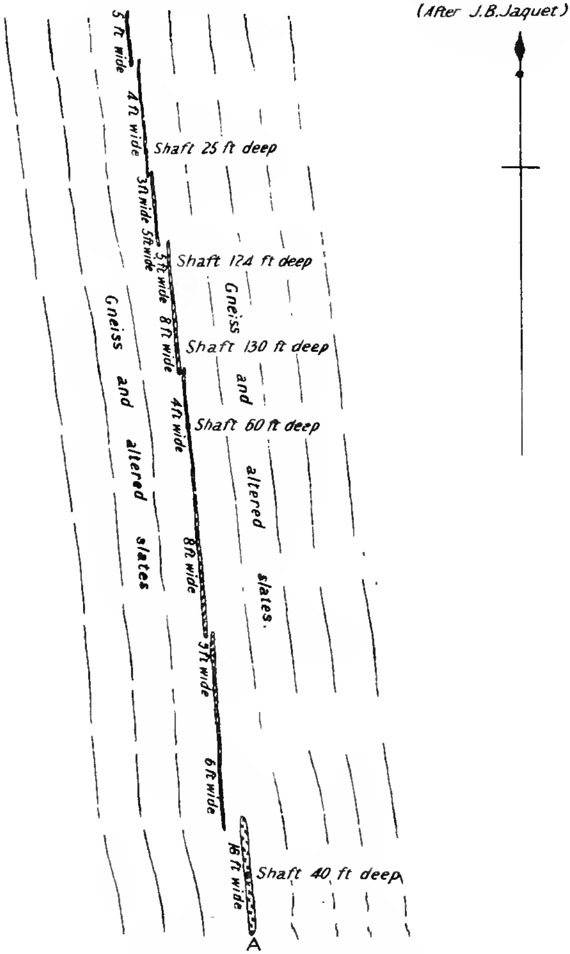
The most northerly lode is known as No. 6, and is situated about a thousand feet north of No. 1, at an elevation of between one thousand and eleven hundred feet above the Murray. It also has an east and west strike, and, so far as it has been tested, varies from four feet six inches to six feet in width. Its outcrop has been traced for a distance of about a mile. It appears to contain fine tin in streaks through the quartz, with only traces of wolfram and tourmaline, while the casing carries coarse tin. A shaft was sunk seventy feet on the lode (which measured four feet six inches in width at that depth), and a tunnel was driven through the granite to cut the lode at right angles. It was said that ten tons of stone crushed from this lode yielded sixteen hundredweight of tinstone. About twenty feet from this lode, and running parallel with it, is a smaller one, varying from four inches to two feet in width, and similar in character, carrying streaky tin in the body of the stone, and coarse tin in the casing.

Between Nos. 1 and 6, four well-defined lodes occur, the outcrops having been discovered to the westward of the two just mentioned, and at a higher elevation on the range. The nearest to No. 6 is a two feet lode, bearing north-west and south-east, and, therefore, probably junctioning with No. 6. No. 5 also probably junctions with No. 6 on the south side. It bears north-east and south-west, and was opened at

# PLAN

of the Tin-bearing granitic dykes occurring on the Mount Eur[illegible]ng Co's property.

Scale 0 200 400 Feet




*Point A is 312 feet from the south boundary of M. L. No. 44.*

62325

*Photo-lithographed by W. A. Gullick, Government Printer, Sydney, N.S.W.*

lease, a Melbourne syndicate having decided to work the deposits by the dredging process ; there is good reason to expect that the method will be effective. No lodes have been disco[illegible]d at the head of Swamp Creek, and it is probable that the tinst[illegible] has been derived from impregnations in greisen.

*The Pulletop Deposits.*—Tinstone also occurs, both in lodes and alluvial deposits, about twenty miles from Wagga Wagga, in the Parishes of Pulletop, Burrandana, and Westby, County of Mitchell. Here again the lodes occur within a short distance of the junction of granite with slate. The gangue of the lodes is quartz, and the tinstone, which is accompanied by a considerable proportion of wolfram, is only present in small quantity. The largest lode has a width of about three feet. Several attempts have been made to work the alluvial deposits derived from the denudation of these lodes, but they have not, so far, proved remunerative, owing to the fact that tinstone and wolfram are present in about equal proportions, and the product was unsaleable in Australia. It is probable, however, that with the introduction of Wetherill separators, payable results could be obtained from the working of these drifts.

*The Burra Burra Deposits.*—At Burra Burra, about sixty-five miles to the north-west of Parkes, an alluvial *lead* containing tinstone was discovered in the year 1893, and was worked for a short time, but the deposit was not found to be very rich or extensive, nor were the lodes, from which the mineral was derived, ever discovered, probably owing to the flat nature of the country. The depth of sinking in the alluvium was as much as twenty feet.

*The Euriowie Tin Lodes.*—In the far western portion of the Colony, at Euriowie and Poolamacca, about fifty miles to the north of Broken Hill, tin-ore occurs under conditions which differ materially from those of any of the deposits hitherto described. The Poolamacca and Euriowie field was reported on by the late Mr. C. S. Wilkinson, in 1887, and by Mr. J. B. Jaquet, in 1894. The ore from this district bears a most marked resemblance to that from the Harney Peak Mines of Dakota, U.S.A., so much so that specimens from the two places cannot be distinguished from one another.

At Euriowie the ore occurs in coarsely crystalline granite or greisen dykes, which intrude metamorphic rocks, such as gneiss and micaceous schist. The granite dykes are variable in their dimensions, being usually from one to twenty feet, and occasionally one hundred feet in width, and terminating abruptly with rounded ends. Mr. Jaquet describes a curious symmetrical arrangement of the dykes which is sometimes seen at Euriowie. Ten or fifteen short dykes may be arranged in the same general direction, and nearly, but not quite, continuous, the posterior end of each being slightly to one side of, and overlapping the anterior end of its neighbour ; so that the series, when shown in plan, resembles a lode which has been intersected and heaved by a number of parallel cross courses. There are, however, no cross courses.

The dykes are composed of coarse crystals of quartz, felspar, and mica, one or two of these minerals predominating at times; thus the rock may be mainly composed of large flakes of mica, or of coarse crystals of quartz and felspar, or mica and quartz. The crystals of tinstone, which vary in size up to two or three inches in diameter, are not evenly disseminated throughout the gangue, but occur in irregularly distributed bunches.

A considerable area of ground was pegged out for mining purposes when these deposits were first dicovered, but probably not more than one hundred tons of dressed ore were despatched from the field before it was abandoned. The scarcity of water for the necessary concentration processes, and the distance which separates this district from the seaboard, are the chief reasons which led to the cessation of mining operations; the deposits will, however, doubtless be worked with profit at some future time.

It will be understood, from the geographical positions of the different deposits already alluded to, that the mineral tinstone is very widely distributed in New South Wales. A glance at the mineral map at the end of this volume will show, however, that it is in the northern portion of the Colony that the principal stanniferous deposits occur. From near Tamworth, tin-bearing rocks extend northwards, with some intermission, up to the Queensland border. The mean width of this area is about thirty miles, and within it are the Bendemeer District; the Inverell and Tingha District; the Emmaville District, including the Nine-mile, Torrington, and the Mole Tableland; the district to the east and south-east of Glen Innes and Deepwater, including Oban, Pheasant's Creek, Back Creek, and Ding Dong; and still further north the Wilson's Downfall District, which may be regarded as an extension eastwards of the Stanthorpe tin-bearing area of Southern Queensland.

At Wylie Creek, thirty miles north of Tenterfield, near Wilson's Downfall, an attempt is about to be made to work the alluvial tin-bearing drifts by means of a centrifugal pump dredge.

*Distribution of Tin-ore in New South Wales.*

The following is a list of the localities from which specimens of stream-tin or lode-tin have been received for assay in the Department of Mines:—

Armidale District.
Ashford, near..
Back Creek, near Bucca Creek.
Baldean.
Ballina (Little River).
Bates, Parish of.
Bendemeer.
Bingara.
Black Mountains, fifteen miles east of.
Bogan Gate.
Bombay Crossing, near Braidwood.
Boorolong.
Borah Creek, near Inverell.
Boro Creek, near Tarago.
Braidwood.
Brill Brill Creek, near Kempsey.
Broadmeadow, twenty-five miles from Glen Innes.
Bukkulla, two and a half miles north of.
Bullock Swamp, Glen Creek.
Bundarra.

Bungonia.
Burra Burra.
Burrowa.

Candelo.
Carcoar.
Clarence District.
Cobar District.
Cogo, Wilson's River.
Cooma.
Cowra District.
Cox's River.
Cudgeon Creek, between Richmond Heads and.

Deepwater.
Dora Dora, east of Albury.
Drake.
Dubbo, near.
Dundee.
Dundee, six miles from. (Hogg's Creek.)

Elsmore.
Emmaville.
Esk River. (McAuley's *lead.*)
Euriowie.
Evan's River.

Galley Swamp. (Bald Hills.)
Glen Creek.
Glen Elgin, near.
Glen Innes.
Germanton.
Gilgai, Inverell.
Grafton, forty miles from.
Grassy Creek, county of Clive.
Grenfell, near. (Seven-mile).
Gulf, The, Tableland.
Gumble.
Gundagai.
Gundle Tin-mine, 35 miles from Port Macquarie.
Guy Fawkes.
Guyra.

Hastings.
Highland Home, Parish of, County of Gough.
Hillgrove.
Hogg's Creek, near Dundee.

Inverell.

Jervis Bay.
Jingellic.

Kempsey District.
Kiandra.

Macleay River.
Mangoplah.
Manildra.
Mann River.
Manning River.
Merool Creek
Mole Tableland.
Molong, fourteen miles west of.
Monaro District.
Moree, forty miles north-east of.
Mount Gipps.
Mount Goonong, Glen Innes.
Mount Hope, near.
Mount Violet, Cooma District.
Mudgee.
Murray, parish of. (Shoalhaven.)

New England.
Newstead.
Nine Mile, Deepwater.
Nymagee (Tallabong Mountain).
Nymagee, sixty miles south of
Nymagee District. (Eurambie Run.)

Oban.
Orange, near.

Pierce's Hill.
Port Macquarie.
Port Macquarie, thirty miles from.
Pulletop, near Wagga Wagga.

Richmond River.
Rockvale, twenty miles from Armidale.
Sandy Creek, Tumut District.
Silverton, twenty-five miles from.
Shellharbour.
Shoalhaven beaches.
Smoky Cape, sixteen miles from.
Stanborough.
Stannifer.
Strathbogie.

Tamworth.
Tarago.
Temora.
Tenterfield.
Tent Hill.
Tingha.
Torrington.
Tumbarumba.
Tumut.

Vegetable Creek.

Wagga Wagga.
Wambrook, near Cowra.
Warialda.
Whitton District.
Wilson's Downfall.
Woodburn.
Wyalong.

*Production of Tin.*

Table showing the quantity and value of Tin, the product of the Colony or of imported Ores refined therein, exported from New South Wales, since the opening of the Tin-fields in 1872.

| Year. | Ingots. | | Ore. | | Total. | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | Quantity. | Value. | Quantity. | Value. |
| | tons cwt. | £ | tons cwt. | £ | tons cwt. | £ |
| 1872 | 47 0 | 6,482 | 849 0 | 41,337 | 896 0 | 47,819 |
| 1873 | 911 0 | 107,795 | 3,660 0 | 226,641 | 4,571 0 | 334,436 |
| 1874 | 4,101 0 | 366,189 | 2,118 0 | 118,133 | 6,219 0 | 484,322 |
| 1875 | 6,058 0 | 475,168 | 2,022 0 | 86,143 | 8,080 0 | 561,311 |
| 1876 | 5,449 0 | 379,318 | 1,509 0 | 60,320 | 6,958 0 | 439,638 |
| 1877 | 7,230 0 | 477,952 | 824 0 | 30,588 | 8,054 0 | 508,540 |
| 1878 | 6,085 0 | 362,072 | 1,125 0 | 33,750 | 7,210 0 | 395,822 |
| 1879 | 5,107 2 | 343,075 | 813 15 | 29,274 | 5,920 17 | 372,349 |
| 1880 | 5,476 6 | 440,615 | 682 6 | 30,722 | 6,158 12 | 471,337 |
| 1881 | 7,590 17½ | 686,511 | 609 6 | 37,492 | 8,200 3½ | 724,003 |
| 1882 | 8,059 0 | 800,571 | 611 0 | 32,890 | 8,670 0 | 833,461 |
| 1883 | 8,680 1 | 802,867 | 445 4 | 21,685 | 9,125 5 | 824,552 |
| 1884 | 6,315 16 | 506,726 | 349 13 | 14,861 | 6,665 9 | 521,587 |
| 1885 | 4,657 18 | 390,458 | 534 18 | 25,168 | 5,192 16 | 415,626 |
| 1886 | 4,640 18 | 449,303 | 326 18 | 18,350 | 4,967 16 | 467,653 |
| 1887 | 4,669 8 | 509,009 | 291 13 | 16,411 | 4,961 1 | 525,420 |
| 1888 | 4,562 2 | 569,182 | 247 8 | 13,314 | 4,809 10 | 582,496 |
| 1889 | 4,408 13 | 403,111 | 241 15 | 12,060 | 4,650 8 | 415,171 |
| 1890 | 3,409 11 | 317,117 | 259 4 | 12,724 | 3,668 15 | 329,841 |
| 1891 | 2,941 5½ | 261,769 | 203 5 | 9,643 | 3,144 10½ | 271,412 |
| 1892 | 3,253 0 | 301,541 | 239 2 | 12,573 | 3,492 2 | 314,114 |
| 1893 | 2,636 17 | 223,139 | 148 1 | 6,604 | 2,784 18 | 229,743 |
| 1894 | 2,611 5 | 179,445 | 190 7 | 7,752 | 2,801 12 | 187,197 |
| 1895 | 2,199 11 | 136,080 | 77 4 | 2,543 | 2,276 15 | 138,623 |
| 1896 | 1,710 4 | 99,212 | 96 19 | 2,905 | 1,807 3 | 102,117 |
| 1897 | 1,140 13 | 70,128 | 14 2 | 560 | 1,154 15 | 70,688 |
| 1898 | 893 17 | 60,565 | 1 4 | 35 | 895 1 | 60,600 |
| 1899* | 821 15 | 98,138 | 4 15 | 290 | 826 10 | 98,428 |
| | 115,667 0 | 9,823,538 | 18,494 19 | 904,768 | 134,161 19 | 10,728,306 |

* Exports of tin refined in N.S.W. from imported ores not included.

# COPPER.

It is proposed to treat the subject of copper very briefly in this article, as full information in regard to the copper deposits of the Colony can be obtained from Mr. J. E. Carne's carefully prepared monograph on "The Copper-mining Industry and the Distribution of Copper Ores in New South Wales,"* recently published by the Department of Mines.

*Different ores of Copper.*—The following are the principal useful ores of copper found in New South Wales.

1. *Native Copper.* Specific gravity, when pure, 8 to 8·9. Native copper is found in most of the cupriferous deposits of the Colony, though not in any great quantities. It usually occurs in the upper or oxidised portions of lodes, as irregular shaped fragments or masses of crystalline or arborescent form, and it is frequently accompanied by cuprite. The largest mass of native copper known to have been found in New South Wales occurred at Reedy Spring, on the Gamboola Estate, near Molong, and weighed one hundredweight. The presence of native copper at this locality was recorded by Mr. S. Stutchbury, in 1852.

2. *Cuprite, or Red Oxide of Copper.* $Cu_2O$. Specific gravity 5·85 to 6·15. Colour red. Contains 88·8 per cent. of copper. This mineral occurs in the upper or oxidised portions of lodes, and is the richest of all the ores of copper.

It is frequently found in contact with native copper, being the direct product of the oxidation of the metal.

3. *Melaconite, Tenorite, or Black Oxide of Copper.* CuO. Specific gravity 5·8 to 6·2. Colour black. Contains 79·8 per cent. of copper. Is the second richest ore of copper. It frequently occurs in a loose powder between the undecomposed sulphide ores and the oxidised ores above them.

4. *Malachite, or Green Carbonate of Copper.* $CuCO_3 + CuOH_2$. Specific gravity 3·9 to 4. Colour bright green. Contains 57·4 per cent. of copper. Forms one of the most common surface minerals in copper bearing deposits, and is generally confined to the oxidised zones.

5. *Azurite, Chessylite, or Blue Carbonate of Copper.* $2CuCO_3 + CuOH_2$. Specific gravity 3·77 to 3·83. Colour azure blue. Contains 55·2 per cent. of copper. This mineral is very frequently found associated with malachite in the oxidised portions of copper lodes.

6. *Chalcocite, Copper glance, vitreous Copper ore, or Grey Sulphide of Copper.* $Cu_2S$. Specific gravity 5·5 to 5·8. Colour blackish lead grey. Contains 79·8 per cent. of copper. Occurs in most of the copper lodes of this Colony, and usually results from the re-deposition of copper which has been naturally leached from the oxidised ores in the upper portions of lodes. Under these circumstances it usually occurs in a massive form.

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* Mineral Resources, No. 6, 1899.

7. *Bornite, Erubescite, Variegated Copper Ore, or Horse-flesh Copper Ore.*—$3Cu_2S, Fe_2S_3$. Specific gravity 4·9 to 5·4. Colour red to brown, and soon becomes iridescent from tarnish. Contains 55·5 per cent. of copper, and 16·4 per cent. of iron. Is an important ore of copper, and is also redeposited from solutions which have naturally leached the oxidised or upper portions of lodes. Was found in extensive bunches (which contained thirty per cent. of copper) in the Burley Jackey Mine near Woodstock.

8. *Chalcopyrite, Copper Pyrites, or Yellow Sulphide of Copper.*—$Cu_2S\ Fe_2S_3$. Specific gravity 4·1 to 4·3. Colour brass yellow, often iridescent. Contains 34·5 per cent. of copper, and 30·5 per cent. of iron when pure. Is one of the commonest and most important of the ores of copper, and is almost invariably found in lodes below the water level. It is to the decomposition of this ore that nearly all copper-bearing minerals, found in the oxidised portions of lodes, owe their origin. It is rarely found, to any great extent, in a pure state, being usually associated with a greater or less proportion of iron pyrites; the two minerals occur in a state of mechanical mixture, forming a massive ore, as, for instance, in the Great Cobar, the Nymagee, the Sunny Corner, and the Lake George Mines. In such cases these ore frequently contain small proportions of gold and silver.

*Early Discovery of Copper.*—There is every reason to believe that copper was the first metal to be worked in New South Wales. The earliest attempt to mine for copper in the Colony was probably made about the year 1844.

In 1845 mines were being worked at Copper Hill, near Molong, and at Lipscombe, Pool's Creek, near Canowindra. In 1847 copper-mining was being carried out on the Summerhill Estate, near Rockley, and in the following year the prospectus of a company, which it was proposed to form for the purpose of working the copper deposits at the last mentioned place, was published in the *Bathurst Advocate*, of the 30th December.

In an official despatch to Earl Grey, dated 1st March, 1849, Governor Sir Charles Fitzroy, advocated the carrying out of a geological survey of the Colony, and in support of his recommendation, stated that "Copper-mines are already in operation in the neighbourhood of Yass, and at Molong, near Wellington Valley. The success which has attended the opening of these mines has, as yet, only been partial, but experiment has not yet proceeded far enough to test, with any certainty, their ultimate productiveness. It is also contemplated, I understand, to open mines in the neighbourhood of Carcoar, in the county of Bathurst, and at Summerhill in the same county, where strong indications of the existence of lodes of sufficient richness to justify their being worked have, for some time, been known to exist."

In 1851, Mr. S. Stutchbury, Geological Surveyor, made the first geological examination of the known copper deposits of the Colony, including those at Summerhill, Coombing, and Cornish Settlement (Carangara). In September, 1851, the Rev. W. B. Clarke reported the occurrence of copper ores a few miles westward of Inverary Quarry in the Marulan District, and also at Boro; the Mulloon Copper-mine was subsequently (in 1872) opened at this locality.

In February, 1852, Mr. Clarke discovered copper and lead ore at Quidong in the Snowy River District.

The following table gives the names and localities of the principal copper-mines of the colony, together with the approximate dates on which mining operations were commenced and the depths to which the workings have been carried.

| Date. | Name of Mine. | Locality. | Depth of Workings |
|---|---|---|---|
| | | | Feet. |
| * 1845 ... | Copper Hill ... ... ... | Near Molong ... ... | 146 |
| 1845 ... | Belubula ... ... ... | ,, Canowindra ... ... | 504 |
| * 1846 } * 1847 } | Summerhill ... ... ... | ,, Rockley ... ... | 90 |
| * 1848 } * 1849 } | Good Hope ... ... ... | ,, Yass ... ... .. | ... |
| 1850 ... | Coombing Park ... ... | ,, Carcoar ... ... | 180 |
| * 1850 ... | Carangara ... ... ... | ,, Orange ... ... | 240 |
| * 1851 to 1865 | Cadia... ... ... ... | ,, ,, ... ... | 222 |
| * | Icely ... ... . ... | ,, Carcoar ... ... | 275 |
| * | Ophir ... ... ... | ,, Ophir ... ... ... | 200 |
| | Britannia ... ... ... | ,, Orange ... ... | 210 |
| | Moonta ... ... ... | ,, ,, ... ... | 60 |
| | Nelson ... ... ... | ,, ,, ... ... | 120 |
| * 1865 ... | Currowong ... ... ... | ,, Lake George ... ... | 168 |
| 1867 ... | Belmore ... .. | ,, Cowra ... ... ... | ... |
| * 1868 ... | Belmore ... ... ... | ,, Delegate ... ... | ... |
| *§ 1868 .. | Goodrich ... ... ... | ,, Wellington ... ... | 150 |
| *†‡1869 ... | Great Cobar... ... ... | Cobar .. ... ... | 540 |
| § 1872? ... | Nuntherungie ... ... | ,, Wilcannia ... ... | ... |
| * 1872–3... | Essington ... ... ... | ,, Rockley ... ... | ... |
| * 1873 ... | Peelwood ... ... ... | ,, Tuena .. ... ... | ... |
| *§ 1873 ... | Wiseman's Creek ... ... | ,, Rockley ... ... | 162 |
| * 1873 ... | Cow Flat ... ... ... | ,, Bathurst ... ... | 180 |
| *§ 1873 ... | Millburn Creek ... ... | ,, Mount McDonald ... | 300 |
| * 1873 ... | Frogmore ... ... .. | ,, Burrowa ... ... | 373 |
| * 1874–5... | Belara ... ... ... | ,, Wellington ... ... | 200 |
| * 1874–5... | Snowball ... ... ... | ,, Adelong ... ... | 136 |
| *§ 1875 ... | Apsley .. ... ... | ,, Rockley ... ... | 250 |
| † 1875 ... | Armstrong ... ... ... | ,, Bathurst ... ... | ... |
| *† 1876–7... | Burraga ... ... ... | ,, Burraga ... ... | 800 |
| † 1877 ... | Burley Jacky ... ... | ,, Woodstock ... ... | 262 |
| *† 1878 ... | New Mount Hope ... ... | ,, Mount Hope ... ... | 400 |
| *† 1878 ... | Great Central ... ... | ,, ,, ... ... | 242 |
| *†‡1879 } ... | Nymagee ... ... ... | ,, Nymagee ... ... | 720 |
| § 1880 } ... | Bobby Whitlow ... ... | ,, Bingara ... ... | 110 |
| *† 1880 ... | Girilambone... ... ... | ,, Nyngan ... ... | 500 |
| *†‡1881 ... | Annandale ... ... ... | ,, Blayney .. ... | ... |
| *†‡1882 ... | Captain's Flat ... ... | ,, Captain's Flat ... | 600 |
| *†‡1895 ... | Cornish‖ ... ... ... | ,, Barraba ... ... | 167 |
| 1895 ... | Mayfield ... ... ... | ,, Burrowa ... ... | 125 |

* Reverberatory furnaces erected. † Working. ‡ Blast furnaces adopted or being erected. § Reopening. ‖ Now known as The Gulf Creek (Limited).

In the early days of copper-mining, in the western portions of the Colony, the industry suffered under great disadvantages, not only in regard to the scarcity of fuel and water, but more especially on account of the great distances over which the ore or metal had to be carried by bullock-teams to the nearest railway-station. In the case of the Great Cobar Mine the copper was conveyed a distance of more than 300 miles over bush tracks through country where there was frequently no grass. The cost of carriage, in such cases, amounted to as much as £42 per ton, so that only a mine of extraordinary richness could have continued working under such a severe handicap. It is hardly surprising, therefore, that most of the earliest copper-mines were worked in a very unscientific manner, the method generally followed being the extraction of the richest oxidised ores, without consideration of the subsequent development of the mine at greater depths. In consequence of this near-sighted policy it followed that the mines generally closed down when the rich ore of the upper levels gave place to poorer sulphides below, and more particularly when the impoverishment was accompanied by a fall in the market value of the metal.

In the old Welsh process the oxidised ores are mixed with copper sulphides, and smelted in reverberatory furnaces, with the result that they mutually reduce one another. The process consists of six distinct operations as a minimum—that is, provided the requisite proportion of oxidised ores be mixed with the sulphides; if, however, no oxidised ores are obtainable, and sulphides alone have to be treated, two extra operations are necessary. It will be seen, therefore, that it is especially desirable for the economic working of a copper-mine, that prospecting operations should be systematically carried out from the commencement, and the sulphide deposits, which are certain to be found beneath the oxidised ores, should be developed at an early stage of the mine's history, in order that the two classes of ore may be smelted in conjunction. If due consideration had been paid in the past to the advantages of this system of mining there can be no doubt that many of our copper-mines which have been obliged to close down, would have enjoyed continued prosperity.

At the present day, however, the world's increasing demand for copper, for industrial purposes, bids fair to maintain a good price for the metal, and, in view of the increased facilities for carriage, which have been, and are still, being effected, by the extension of the railways, and in consequence also of the improvements which have been introduced for the treatment of low-grade sulphide ores, there is every reason to believe that a new era of prosperity is opening for the copper-mining industry in New South Wales.

Low-grade copper-sulphide ores, containing small proportions of gold and silver, can now, if occurring in large deposits, be profitably treated by the process known as pyritic smelting, which is effected in water-jacket blast furnaces. The minimum percentage of copper which will render an ore payable under this process will depend upon local conditions, as well as upon the composition of the ore itself; but an ore of suitable character, containing as little as two per cent. of copper, together with very small proportions of the precious metals, can be profitably treated under favourable conditions.

Theoretically, in treating thoroughly favourable ore by pyritic smelting, no extraneous fuel is required, the necessary heat being obtained by the oxidation of the sulphur in the ore by a hot-air blast; hence there is an enormous saving in cost as compared with the ordinary smelting process in reverberatory furnaces; and, moreover, no preliminary roasting of the ore is required. The iron contained in the ore is oxidised, and, combining with the silica, forms a slag. If there be not sufficient silicious matter in the ore, low-grade auriferous quartz, which could not be profitably treated *per se*, can with advantage be added, as the silica forms a liquid flux with the iron, and the gold is recovered. The copper is reduced to the condition of matte, a lower sulphide (which is easily separated from the slag after cooling), and it collects and carries down with it the gold and silver. The matte is afterwards transferred in a molten state to a "converter," where the remainder of the sulphur is oxidised by an air-blast, and the copper, still carrying the gold and silver, is reduced to the metallic state. Finally, the precious metals are separated from the copper by the electrolytic process.

Where the ore is not absolutely suitable for pyritic smelting, it may be practicable to treat it by what Dr. Peters terms "partial pyritic smelting," in which case a hot blast is employed, with the addition of from 1·5 to 5 per cent. of coke to the charge.

The presence of zincblende, or galena, in appreciable quantities, in the copper sulphide ore, has an injurious effect on the process of pyritic smelting. Zinc especially tends to prevent the easy separation of the matte from the slag, by decreasing the specific gravity of the former. Moreover, the presence of zinc in metallic copper has the effect of impairing the malleability of the latter metal. So thoroughly is it recognised that zinc is an objectionable ingredient in copper ores, that most public smelting companies impose a charge of 1/- per unit for all zinc over 10 per cent.

The presence of bismuth in copper is also objectionable, as it causes a difficulty in refining the metal. The Great Cobar Copper-mining Co. have experienced much trouble in the past from the occurrence of bismuth in their ore, and it also occurs in the iron ores which have been used as fluxes for the New Mount Hope copper ore. In the case of the Great Cobar ore, the disadvantage arising from the presence of bismuth is, however, more than counterbalanced by the proportion of gold contained in the sulphides. At the present time the ore from this mine is understood to yield, on an average, from $3\frac{3}{4}$ to 4 per cent. of copper, and $2\frac{1}{2}$ dwts. of gold per ton, and, as the ore bodies are of great size, very large profits are being obtained from its treatment.

*Mode of Occurrence of Copper Ores.*—Deposits of copper ore occur in New South Wales as (1) Lodes, (2) Stockworks, and (3) Impregnations.

(1.) *Copper Lodes* may be further divided into Fissure Lodes, Bedded Lodes, and Contact Lodes. The two first named are found intersecting rocks of Silurian, Devonian, and Carboniferous age, as well as in the igneous rocks which have intruded these palæozoic sediments. Contact Lodes are found occupying spaces between intrusive igneous rocks and the older sedimentary formations.

(2.) *Stockworks* formed of copper ores are not of frequent occurrence, but a notable example occurs in the New Mount Hope Mine, where a felspathic rock is intersected by numerous minute veinlets of blue and green carbonates of copper, crossing one another in all directions.

(3.) *Impregnations.*—Native copper occurs in minute scales or grains disseminated through beds of tuffaceous shales, which form passage-beds between the productive coal measures (Permo-Carboniferous), and the overlying Narrabeen shales of the Hawkesbury Series (Triassic). These cupriferous shales have been described in detail by Professor David, who mentions that they occur at Bulli, at a height of 700 feet above the Bulli coal seam ; at Newington, near Parramatta, where they were met with a diamond-drill bore ; and at Holt-Sutherland, and Heathcote, where they were also intersected by diamond-drill bores. The two latter localities are eight miles apart, and it may, therefore, be assumed that these copper-bearing shales are continuous over wide areas near Sydney, at a depth of about 1,500 feet from the surface. They have a mean thickness of about one foot, and taking the average of a number of assays, they probably contain at the rate of about ·15 per cent. of copper, 7 dwts. of silver per ton, and a trace of gold. They are not of sufficient richness, therefore, to be of any commercial value at present.*

The following detailed description of the Great Cobar Mine, which has been the most successful of all the copper mines hitherto opened in this Colony, is taken from Mr. J. E. Carne's work on "The Copper-mining Industry, and the Distribution of Copper Ores in New South Wales."

*Great Cobar Copper-mine.*—This mine is situated 110 miles south of Bourke, and 459 miles west, by rail, from Sydney. The Cobar Company's property consists of 1,100 acres of freehold land, on a portion of which the town of Cobar is built.

*Historical.*—"Cobar (or Copar), in the aboriginal, signifies "Raddle" (earthy iron oxide), and, from the outcrop of the Cobar lode, the aboriginals formerly obtained it for decorative purposes ; in process of time a small circular excavation resulted from scooping out the soft ochreous material, forming a catchment for water, and serving as a 'native well.'"

"In 1869, two Danes, Thomas Hartman and Charles Campbell, engaged at the time in boring for water in this district, camped at the native

* Quite recently these cupriferous shales have been recognised by Mr. J. E. Carne, F.G.S., in the Capertee Valley, proving that they occupy a permanent horizon in the Triassic Series.

well, and were attracted by the rusty sediment at the bottom, and the blue and green stains on the sides, and, for a limited extent, round it. Neither were at the time acquainted with copper ores. The story of the facts, leading to the discovery of the real nature of the colouring which arrested their attention, is in dispute. Briefly, the account of the surviving discoverer—Hartman—is that on raking the ashes of the camp-fire made alongside the well, he discovered beads of metallic copper, which he took direct to Bourke, and there displayed. The conflicting story is, that Hartman and Campbell, taking with them specimens of the coloured rock, proceeded on their journey until they fell in with a Cornish woman—Mrs. Kruge—the wife of a countryman, who at once recognised the true nature of the colouring. On ascertaining its value, Hartman and Campbell returned to Cobar, and, subsequently (on the 6th October, 1870, according to Mr. Russell Barton), at Fort Bourke, secured the land as a Mineral Conditional Purchase of 40 acres, in conjunction with the late Joseph Becker of that place. The latter, in May and June, 1876, also secured 40-acre blocks adjoining the Cobar on the north and south. In January, 1876, the South Cobar Mining Company was amalgamated with the Cobar, under the present title of "Great Cobar."

"From a recent inspection of the portion of the outcrop and the native well remaining intact, it seems improbable that native copper occurred directly on the surface, in which form alone could it have been melted into the beads reported by Hartman, for there is no question that the small camp-fire could not have reduced the metal from its ores; circumstantial evidence, therefore, supports the rival story; but, none the less, the credit of discovery rests with Hartman and Campbell, whose intelligent curiosity prompted transport of specimens which had drawn their attention. Lack of this vauluable trait has frequently led to sources of wealth being undeveloped for years, until the advent of one of greater inquisitiveness or knowledge. In contrast to the action of the Cobar discoveries, the writer recalls the statement of a shepherd he met at Mount Hope Copper Mine shortly after its discovery. Located within a few hundred yards of the outcrop on Mount Hope, he had often remarked the blue and green colours as he followed his flock over it, but intelligent prompting was wanting in this case. Prior to the discovery of payable tin ore in New England in 1872, the gold-miners were greatly hampered by the heavy black sand (tin oxide) in their sluices, which caused endless trouble in separating the gold. Instances might be multiplied, but sufficient has been written to illustrate the value of intelligent curiosity in regard to Nature's mineral treasures, many of which, unlike copper, she dresses in very unattractive garb, but which, nevertheless, possess distinctive characteristics, either of form or gravity, which compel attention. Notice might here be drawn to the ready means of identification, available to even the poorest, which the Government of the Colony has wisely established. A free laboratory, and experts to determine the nature and value of any substance discovered, without cost to inquirers, has been provided in connection with the Department of Mines and Agriculture.

"Shortly after operations were started at Cobar by Hartman and Campbell, Mr. Russell Barton—since well known in connection with copper-mining in the Colony—passing the locality, visited the mine, and being greatly impressed with its possibilities, from the insight he had gained in South Australian copper-mining, purchased an interest. Rich ores were extracted from near the surface, and despatched by team to the Darling River, at Bourke, and thence by river steamer to Port Adelaide Smelting Works, South Australia. Some 3,000 tons are reported to have been thus disposed of at a profit. In January, 1876, the Cobar and the Southern Cobar Copper-mining Companies were amalgamated under the title of 'The Great Cobar Copper-mining Company (Limited),' in 80,000 shares of £1 each."

"Extraordinary difficulties faced the new company. A mine situated 459 miles (railway measurement) from the seaboard, in an arid tract, destitute of natural drainage channels (the nearest being the Bogan River, 80 miles distant), subject to drought, with an unevenly distributed rainfall, averaging only 17·21 inches, according to the Government Astronomer, and a greedily-absorbent sandy soil. The nearest railway at the beginning of operations was Blayney (opened in November, 1876), distant, by the present railway line, 287 miles from Cobar. In April, 1877, the Orange extension was opened, which reduced the distance to 267 miles. The ordinary roadway, however, probably covers a much greater distance between the points mentioned. That the Company was enabled, under such handicaps, to pay dividends amounting to more than double the total capital, is eloquent testimony to the richness of the mine. In 1889 the Company had to suspend operations, owing to the extremely low price of copper and excessive cost of transport. The failure of the *Société des Metaux*, and the collapse of the 'copper boom' it had originated, were the direct cause of the Company's suspension, as an agreement had been entered into for a term of three years with the *Société* for the purchase of the entire output from the Cobar Mine at £60 per ton on board ship at Sydney. The Company intended resuming operations on completion of the branch railway line from Nyngan to Cobar. In 1893, however, the mine was let on tribute to the present syndicate, who began operations when the average value of copper was but £39 per ton, and successfully introduced the cheaper and more rapid blast-furnace method of reduction, which has revolutionised the copper industry at Cobar. A previous attempt with blast furnaces (not water-jacketed) was made in 1885, when three were erected at a cost of over £5,000. After a short campaign with charcoal fuel, they were discarded, though the mine manager, Mr. J. Dunstan, regarded some of the experiments as satisfactory. 325 tons of ore were smelted in these furnaces. The cost of charcoal alone would have rendered profitable working impossible at this date."

"Rapid and certain railway transit has effected no less complete a revolution in cost of production. Prior to the advent of the railway the Company was dependent on teamsters for freightage to and from the mine, and the latter again were entirely dependent on the seasons. During a drought, in 1882–3, it was found almost impossible to maintain the necessary supply of firewood, whilst the stock of copper in the sheds at the mine increased to over 1,200 tons, owing to the impossibility of transport by team, over 300 miles of drought-stricken country to the nearest railway."

"Cobar, like Broken Hill, affords a striking object lesson of the vital influence which mining exerts on the material progress and prosperity of a country. What other industry can compete with the rapidity of the restless energy with which it overcomes tremendous difficulties, and reclaims arid tracts of civilisation."

"During the operations of the Company, from 1876 to 1893, 213,182 tons of ore were raised, 23,610 tons of copper produced, and £154,000 were paid in dividends up to 1889. Further dividends have been paid under the present tribute."

"*Geological and descriptive.*—In 1880, the Writer accompanied the late Geological Surveyor L. Young to Cobar. From the report published by the latter in the Annual Report of the Department of Mines for the year mentioned (p. 262) the following notes are extracted :—

"'The workings are on what is known as the West lode. On the surface there appear the outcrops of two adjacent parallel lodes ; it is my opinion, however, that all three form one lode, being only separated by pieces of country known to miners as *horses.* The characteristic point in the Cobar Mine is the great variation in the width of the lode, viz., from a mere film to 100 feet. . . . The ore from the 50-fathom level is composed of solid yellow sulphide of copper ; from the 39-fathom level, of carbonates, metallic copper in films, red oxide, grey sulphide, and brown iron ore, the lode being fairly compact. At the 26-fathom level the ore is principally carbonate of copper, mixed with iron ore, while the lode is less compact.'"

"The physical features of Cobar may be briefly described as a monotonous stretch of level country, above which a few hills and ridges of low elevation rise conspicuously. Cobar lode forms a low ridge, having a north and south trend. Fort Bourke, and the Peak ridges, of greater elevation and length, have parallel trends south and east of the former. The country consists of sandstones and slates, of, probably, Silurian age. On the geological map of the Colony the elevated peaks have hitherto been coloured as Devonian, but from the writer's observations, and the identification of Silurian fossils by the Palæontologist, Mr. W. S. Dun, in similar rocks, at Bobadah, and also in the limestone etween Cobar and Nymagee, as well as the extreme lithological contrast between these highly cleaved and folded rocks, and the outliers of approximately horizontally bedded sandstones and conglomerates—noted particularly between Mount Hope and Euabalong and at Mount Boppy—it is more than probable that the Cobar rocks are older than Devonian."

"To the north-west of Cobar, on Tindary Station, Mr. Chesney, C.E., obtained undoubted Devonian marine fossils, but the site has not yet been geologically examined; it will probably prove an outlier, similar to those already alluded to."

"The elevated areas at Cobar are the direct result of mineralisation, the indurating influence of which has rendered them less amenable to subærial disintegration and degradation, than the surrounding country. This feature lessens the prospect of any extensive metalliferous deposits occurring in the level country. The principal indurating agencies in the high metalliferous areas are silica and iron. Infiltrated masses of the former are conspicuous at Fort Bourke Hill, where massive sandstones have been converted into quartzite by the investing silica. The slates of these regions are highly ferruginous."

"*Outcrop.*—Contrary to the general idea, the Cobar Copper Lode did not make a really strong outcrop. In only one place, near the site of the native well, did copper ores show at the surface. Three small patches of iron-oxide were exposed, two near the well, the third at the site chosen for 'Renwick's Shaft.' The outcrop consists of highly ferruginous slate, which in the case of the 'Middle' and 'Eastern' lodes ($2\frac{1}{2}$ and $4\frac{1}{2}$ chains east of the main lode) is highly silicified. The 'Middle' lode only has been pierced below ground, in a cross-cut extended 140 feet from the 54-fathom level, at the north end of the main workings, and also from the 34-fathom level near Becker's Shaft. Twenty-one feet of mineralised slate, in one instance, and thirty feet in the other, were passed through, constituting good concentrating lodestuff (yellow copper ore)."

"The comparatively poor outcrop of gossan on the main lode afforded little indication of the immense ore bodies below; neither does the outcrop of the 'Middle' lode betray the slightest surface evidence of its cupriferous contents beneath. Hence there is reason for anticipating the occurrence of payable ore bodies, possibly of considerable extent, in both the 'Middle' and 'Eastern' lodes, which are, as yet, practically intact. Both these lodes possess strong outcrops of ferruginous slate and quartz. South of the main shaft a crosscut was driven 90 feet east, but this was insufficient to reach the 'middle' lode; crosscuts at least 330 feet long are necessary to intersect the two eastern lodes."

"*Development.*—The deepest shaft is 90 fathoms (540 feet). From this level drill bores were put down diagonally to a depth of 120 feet, proving a width of lode equal to 40 feet, and the ore tenor about 4 per cent. of copper. Water was struck at 601 feet in the bore."

"At the north end the Cobar lode splits; the eastern branch made into good ore, but the western has not been followed. The present working faces, at the 74 and 90 fathom levels, equal 50 feet each in width, increasing in some places to 70 feet, of solid iron sulphides containing varying proportions of copper pyrites."

"The oxidised zone extended to about the 250 feet level. Though a small proportion of oxidised ores is still being obtained from this zone, the visible supply has been practically exhausted."

"*Winning the Ore.*—Wherever possible, the Cobar Syndicate has wisely adopted the contract system in stoping and trucking below ground, with satisfactory results to both parties. Drilling is principally performed by compressed air drills, though a few contract parties are still using hand-drills. The contract price for mining is about 4s. per ton. The output amounts to about 2,000 tons per week, but will shortly be considerably augmented, as two additional blast furnaces are being erected to compete with a larger output during the remainder of the Syndicate's tributing tenure. The output, however, cannot be increased beyond a moderate total, because of the limited shaft-room."

"Though electric lighting has been installed above ground, it has not yet been introduced below. The adoption of ordinary coal-miners' oil lamps, however, is a considerable advance on candles, both as regards light and convenience, especially for the truckers."

"Haulage is, necessarily, comparatively slow, owing to the very restricted dimensions of the two working shafts. On reaching the surface the loaded trucks are run to the heap-roasting ground on the east fall of the ridge, close to the shafts, and their contents dumped directly on to the heaps in course of preparation."

"Since the advent of blast furnaces the old tips have been turned over and carefully sorted, the great bulk of the discarded material being turned to advantage, as it served admirably for fluxing purposes, yielding at the same time its quota of valuable metal. Likewise from the earlier fillings below ground, and from the walls of the lode, much low-grade yet workable ore has been extracted, which was discarded or left whilst following the richer central portions of the lode."

"*Composition of the Ores.*—The composition of the rich ores from the upper levels may be well studied in the following analysis made by W. A. Dixon, F.C.S., F.I.C. (Ann. Rept. Dept. Mines for 1878, pp. 25–29). It will be noticed that bismuth was present in marked quantity, but apparently most of it was eliminated during smelting operations, as revealed by the analysis of the copper produced from the ores analysed (No. 65). It is noticeable that in a recent analysis of drillings from the 50, 74, and 90 fathom levels (sulphide zone), its presence was not detected. Possibly it may be confined to certain regions of the lode, and, in the oxidised zone, leaching and re-deposition may have concentrated it in appreciable quantities."

"On the walls of the lode, at the present working levels, a little zinc blende and galena make at intervals, which are roughly discarded at the surface."

Analysis of Cobar Copper Ores, by W. A. Dixon, 1878.

| Assay Nos. .. .. | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 |
|---|---|---|---|---|---|---|---|---|---|---|
| Silicia .. .. | 4·26 | 2·06 | ·62 | 1·92 | ·96 | 20·68 | ·56 | 10·64 | 29·28 | .. |
| Copper .. .. | 22·84 | 54·06 | 37·87 | 54·93 | 26·47 | 63·24 | 57·42 | 42·79 | 38·23 | 99·346 |
| Antimony .. .. | ·61 | traces | traces | traces | ·46 | ·13 | traces | .. | .. | ·029 |
| Bismuth .. .. | 2·11 | 1·47 | 1·90 | 2·58 | 2·17 | 1·18 | ·95 | 1·24 | ·21 | ·419 |
| Lead .. .. .. | ·27 | ·41 | ·45 | .. | | .. | 7·79 | . | .. | ·086 |
| Arsenic .. .. | traces | .. | .. | .. | .. | .. | .. | .. | .. | ·011* |
| Iron .. .. | 39·20 | 7·28 | 30·80 | 18·26 | 39·09 | 1·74 | 4·99 | 8·49 | ·78 | ·083 |
| Zinc .. .. .. | ·35 | .. | .. | .. | .. | .. | .. | | .. | . |
| Silver .. .. | traces | traces | .. | .. | .. | .. | .. | | .. | ·026 |
| Nickel .. .. | .. | traces | traces | .. | | .. | .. | .. | .. | .. |
| Magnesium .. .. | .. | 5·33 | .. | .. | .. | .. | traces | .. | .. | .. |
| Sulphur .. .. | 24·11 | 4·18 | 18·63 | 14·48 | 27·46 | 5·70 | 11·67 | .. | .. | .. |
| Carbonic Acid .. | .. | 9·97 | .. | .. | .. | traces | 5·87 | 14·37 | 17·47 | |
| Water .. .. | .. | 3·41 | .. | .. | .. | .. | 4·60 | 7·04 | 3·79 | .. |
| Oxygen, loss, undeterminable .. | 6·25 | 11·83 | 10·00 | 7·83 | 3 39 | 7·33 | 6·15 | 15·43 | 10·24 | .. |
| | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 | 100 000 |

* Traces of Arsenic, Nickel, Cobalt, Gold, and loss.

Sample 56. Copper pyrites and magnetite.
,, 57. Red oxide, copper glance, and ferric oxide.
,, 58. Copper pyrites, red oxide, and ferric oxide.
,, 59. Copper glance, with ferric oxide.
,, 60. Copper pyrites and magnetite.
,, 61. Copper glance and red oxide.
,, 62. Copper glance, with malachite.
,, 63. Malachite, with ferric oxide.
,, 64. Azurite.
,, 65. Copper from the above.

"The nature of the sulphide ores at Cobar is partially revealed by the following analysis made in the Departmental Laboratory from drillings obtained by the Writer, through the courtesy of Mr. Langworth, of the Cobar Syndicate. The sample represented an average of two days' drilling at the 50, 74, and 90 fathom levels; the copper contents, however, do not represent the average value of the ore in these levels, which according to the smelting returns, ranges between 3·9 and 4·5 per cent."

| | |
|---|---|
| Moisture at 100° C. ... ... ... ... ... | ·20 |
| Metallic iron .. ... ... ... ... ... | 42·65 |
| ,, copper ... ... ... ... ... | 10·15 |
| ,, lead... ... ... ... ... ... | trace. |
| ,, zinc... ... ... ... ... ... | trace. |
| Silica ... ... ... ... ... ... ... | 16·09 |
| Alumina .. ... ... ... ... ... | ·44 |
| Lime ... ... ... ... ... ... ... | absent. |
| Magnesia ... ... ... .. ... ... | ·34 |
| Sulphur ... ... ... ... ... ... | 20·74 |
| Sulphur trioxide ($SO_3$) ... ... ... ... | ·23 |
| Oxygen (by difference) ... ... ... ... | 9·16 |
| | 100·00 |

Silver at the rate of 1 oz. 2 dwts. 21 grs. per ton.
Gold a trace (under 2 dwts. per ton).
NOTE.—A large amount of magnetite is present in this sample.

"The proportion of iron is complicated by the admixture of fragments of metallic iron broken from the drills, which could not be removed without loss of a portion of the magnetic pyrites present, as well as that portion of the iron saturated with oxygen (magnetite). The occurrence of oxidised ore at this level seems unusual, but it should be stated that the level is free from water, and quite dry."

"*Preliminary treatment of the ores.*—Though the Cobar sulphides are eminently suitable for pyritic smelting, the Syndicate has not deemed the advantage thus gained sufficient to induce it to incur the cost of providing a hot blast, without which pyritic smelting can not be efficiently maintained.*

"As the ore comes from the stopes it is piled on the roast-heaps without extra care. In forming the roast-heaps the V system is roughly followed, sufficient space being left between two adjacent heaps to admit of a third V-shaped filling between, when the former are under way. A rough foundation of wood is laid down, and in the case of the later formed central heap, it is carried up the sides of the adjoining heaps. Apparently little attention is paid to flues for ventilation; doubtless the large size of the ore blocks afford sufficient in the cavities between them to obviate the necessity for special preparation to secure it. The heaps take an elongated form from the raised tramway used for stowing, and contain from 2,000 to 4,000 tons. A little ragging is spread on the top, but scarcely any on the sides. The fines, apparently, are little used for covering, being mostly roasted separately in a circular kiln excavated in the outcrop."

"The absence of sufficient covering accounts for the evidence of too great heating in parts of the roast heaps, where fusion has taken place to a considerable extent. About three weeks are allowed for a roast (according to Mr. Longworth, the managing shareholder). The roasting heaps are well situated on sloping ground, which affords excellent drainage. The natural aridity of the climate disposes of the necessity for provision being made for recovery of copper carried away as soluble salts from roast heaps during rainy weather."

"Owing to the long campaign with reverberatory furnaces at Cobar, the country has been devastated of suitable firewood for a radius of many miles. The wood required for roasting costs 15s. per ton for dry 5 feet lengths, and 12s. 6d. for green. The consumption of firewood in the reverberatory furnaces averaged about 70,000 tons per annum. In 1889 a trial was made with coal from one of the top seams of the Dubbo Coal-field (Bablimore ?). Mixed with wood it answered fairly well in a reverberatory furnace, and about equally as well, mixed with charcoal, in the blacksmith's forge."

"*Smelting.*—The furnace charges consist generally of the following proportions :—

| | | |
|---|---|---|
| 8 | cwt. of | raw sulphides. |
| 8 | ,, | calcined do |
| †4 | ,, | oxidised ore, slate, dry gold, and silver ores, &c. |
| 4 | ,, | coke. |

---

* Arrangements are now being made for the adoption of pyritic smelting.

† When slag from the fore-hearths is used—about every second charge—it takes the place of this item.

"The first reduction brings the matter up to about 30 to 35 per cent. tenor, in which form it is sent to the Syndicate's roasting and refining plant at Lithgow, where some 16 reverberatory furnaces are in use."

"The smelting plant at Cobar consists of four 80-ton water-jacketed blast furnaces, with a working capacity of about 120 tons per 24 hours, but it has already been announced that two additional furnaces are to be at once erected."

"*Gold in Copper Ores.*—Though gold was early known to be present in the Cobar Mine, and, in a free state, was occasionally noticed in the oxidised ores, no attempt was made to turn it to account until the present syndicate began operations in 1893–4. In 1882 Mr. Russell Barton secured a specimen of malachite showing coarse gold, and the Company's caretaker, Mr. W. Gillard, has, in his collection, a specimen of slate from near the outcrop, containing a rich seam of scaly gold."

"Cobar copper must for years have proved a lucrative investment for metal buyers in England, who secured it at a lower market rate than Chilian bars, notwithstanding its valuable gold and silver contents. Possibly the difference in market value between the Cobar and Chili metals was sufficient to defray cost of further refining, leaving the precious metals as clear profit. In 1881 an assay was made, in the Departmental Laboratory, of a sample of the Cobar copper obtained by boring through several ingots, with the following results :—

| | |
|---|---|
| Gold ... ... ... | 2 oz. 12 dwts. 4 grs. per ton. |
| Silver ... ... ... | 1 ,, 5 ,, 0 ,, |
| Copper ... ... ... | 92·65 per cent. |

"As these results were made known at the time, it appears strange that no advantage was derived from the knowledge. Mr. Barton—at one time Chairman of the Company—attributes the omission to the fluctuating results of tests of the surface ores, portions of which gave fair gold value, others almost negative results ; a natural outcome of the leaching and re-precipitating processes to which the upper levels of the lode had been subjected. As gold is less susceptible to natural leaching solutions than copper, it remains to enrich the gossany ores from which the copper had been wholly or in part removed. The re-precipitated or secondary copper ores would thus become richer and more concentrated, but impoverished in gold; hence the fluctuating returns of assay samples, which appear to have depreciated the importance of the presence of gold, even in small quantities, in the ores, notwithstanding the well known collective influence of metallic copper on the precious metals in smelting. Mr. Barton states that the gold contents of the copper produced during early operations varied from half an ounce to three ounces per ton. Not till the latter half of 1894 did the Company draw the attention of buyers to the presence of gold and silver in their copper in workable quantities. The immediate result was an advance of about £7 per ton over the current quotations for Chili bars."

"The sulphides from the present working stopes are reported to yield from $2\frac{1}{2}$ to 3 dwts. of gold per ton. Concentration at the present day is extreme compared with past operations, and probably the average proportion of gold in the sulphides, though lower, is more constant and even than was the case in the oxidised ores. In smelting 10 to 20, and even 30 per cent. ores, concentration is very slight compared with smelting ores of a 3 or 4 per cent. tenor, hence the gold and silver contents are considerably higher in the metal produced from the latter. The market value of the Cobar copper is now enhanced some £20 odd per ton, by the contained gold and silver. This great enrichment is not due, however, solely to concentration of the indigenous gold of the Cobar mine, for the quantity is largely augmented by use of gold and silver ores from other mines, as fluxes in the blast furnaces; and herein lies the great potentiality of the pure iron and copper sulphides of Cobar, their importance as fluxing bases for dry (siliceous) gold and silver ores cannot well be over-estimated. At the Peaks, about five miles south of the copper mine, the Cobar Syndicate has secured a gold and silver mine (Conly and Barrass'), and is working it in conjunction with the former. The better class of gold ore is treated in a battery locally; the lower grades, which, however, are fairly rich in silver—containing about 30 oz. per ton, and 3 dwts. of gold—are carted to the smelting furnaces for fluxing purposes. The Peak lodestuff consists of soft rotten slate, with harder cherty bands, and quartzite; in the ferruginous joints and cavities silver chloride is freely visible."

"The sulphides of Cobar consist largely of pyrrhotite (magnetic pyrites), with pyrite and chalcopyrite, equivalent to a smelting return of about $3\frac{3}{4}$ to $4\frac{1}{2}$ per cent. of copper. They are remarkably free from silica—16·09 per cent., according to the analysis of the drillings already quoted—though not approaching the purity of Mount Lyell ore in this respect. The importance to the field of the low percentage of silica, in the immense sulphide deposits of the Cobar Mine, cannot be over-estimated, as it affords a cheap and efficient means of extracting the gold and silver contents of some of the neighbouring mines, especially those in which copper occurs too sparingly for separate metallurgical treatment, yet too pronounced for ordinary battery or cyanide processes. Silica is necessary in the furnace charge to combine with the abundant iron of the sulphides to form a fluid silicate of iron slag. The siliceous gold and silver ores of the adjacent mines are just what is requisite for proper fluxing requirements. According to Dr. Peters, jun., a siliceous schist or slate in itself is preferable to pure silica (quartz) in matte roasting, and, doubtless, also in reducing. The advantage to a smelting company of being able to command siliceous flux, having of itself intrinsic value, is immense, whilst an equivalent benefit is derived by the owners of such ores. In some public smelting works a mutual gain is derivable from payment of the actual value of the gold and silver contents of dry siliceous ores, without deductions other than freight, in return for the necessary flux thus obtained, almost free of expense."

"If the cost of railway transport* could be so reduced as to enable matte-roasting to be carried on profitably at Cobar, the amount of dry gold and silver ores, for fluxing purposes, could be further increased. The large fluxing base at the command of the Cobar Company, opens up the most extensive problem of the field. Large as is the scale on which operations are now conducted, they are capable of still further development. However unpopular the idea of huge trusts and combines may be in the public mind, there is no question that only under such conditions of consolidation will some of the extensive low-grade cupriferous gold and silver deposits of the vicinity be turned to greatest account. For though at present the Cobar Chesney Mine is the only other of the Cobar group that has developed copper ores of commercial importance, there is every reason to anticipate, at all events, an amount of copper ores in the lower levels of the others, sufficient to render unprofitable any method of extraction other than smelting in the way indicated."

"If combination be eschewed, an alternative scheme presents itself to the owners of the deposits mentioned, viz., utilisation of the Cobar furnace slags for fluxing purposes, as these are capable of absorbing a further amount of silica. The proper proportion of silica in blast-furnace slag, according to Dr. Peters ("Modern Copper Smelting," 5th Edition, p. 185) lies between 24 and 36 per cent., and may be raised or lowered about 6 per cent. without seriously affecting the running of the furnace, but every unit in excess will reduce the amount smelted in 24 hours."

"Taking the maximum limit, 36 + 6 = 42 per cent. can be absorbed without serious inconvenience, and it is well known that this limit is frequently exceeded. The above authority, in the 7th Edition of the same work, p. 282, states that probably the most siliceous slag made regularly in the world in blast furnaces, is that of the Saengerhausen Smelter, on Mansfeld ores of Prussia, viz., 53·83 per cent. of silica."

"Robert Sticht, of Montana, U.S., in an article on Pyritic Smelting contributed to Peter's "Modern Copper Smelting," 7th Edition, p. 402, states that "The amount of silica in the slags may vary from below 28 to above 48 per cent. to suit the ores treated." Hence with pyritic smelting at Cobar, the amount of siliceous flux may be largely increased, especially if, in addition, the amount of sulphur be so regulated as to avoid the formation of excess of protosulphide of iron in the matte, leaving the protoxide of iron free to combine with the silica, instead of with the excess of sulphur, over and above the amount required to satisfy the copper. The proportion of sulphur to copper, in sub-sulphide of copper is 1 to 4, whilst that of sulphur to iron in ferrous sub-sulphide is 1 to $1\frac{3}{4}$."

"Herbert Lang ('Matte Smelting,' 2nd Ed., 1898, p. 37) states that 'Slags have been and are being made in practice which contain as much

* Freight on coal and coke, Lithgow to Cobar, 16/- per ton.
„ matte to Lithgow, 14/8 per ton.
„ copper, Cobar to Sydney, 41/3 per ton.
„ „ Lithgow to Sydney, 12/- „

as 65 per cent. of silica. In reverberatory furnaces a high proportion of silica can be slagged off.'"

"A slight insight into the value of the Cobar slags for fluxing purposes may be gained from the following analyses of samples taken at random by the Writer :—

| | Copper. | Silica. | Iron. |
|---|---|---|---|
| From reverberatory slag dump ... ... | 0·66 % | 35·49 % | 41·40 % |
| ,, blast furnace ,, ,, ... ... | 0·20 % | 27·31 % | 45·28 % |
| ,, ,, ,, forehearths... ... | 0·31 % | 29·29 % | 44·14 % |

Whilst on the subject of gold extraction, one other step in advance may be indicated, viz., electrolytic refining of the copper, and separation of the gold and silver contents, the absence of which at present entails a reduction of £4 per ton in the value of the copper, as a set-off against cost of extraction. Such a plant would, perhaps, be most advantageously situated at Lithgow, in connection with the roasting and refining works already established, where coal is obtainable on the ground. In the absence of cheap water power, for generating electricity, it is, however, doubtful if the cost of extraction could be lessened locally. This, however, is purely a financial question."

"The following particulars are extracted from a report by Mr. John Munday to the Chairman of Directors of the Great Cobar Copper-mining Company (Limited), dated August 7th, 1897. The condition of the mine, and the longitudinal and lateral extension of the ore-bodies at this date can be readily grasped from the reliable figures quoted."

"'In the shallow ground there are workings on the lode to an extent of 1,300 feet in length. Below the 37-fathom level the ore is separated into four bodies striking vertically downward. The northernmost of these ore-bodies is situated near Becker's shaft, and is 130 feet long, averaging 20 feet wide, and has been worked out down as far as the 54-fathom level. This body of ore has also been sunk upon by Becker's shaft to the 74-fathom level, but is otherwise intact. The middle ore-body commences at 260 feet south of the above, and extends southward in length 320 feet, and at the 70-fathom level stope, where its dimensions are best ascertained, its average width is not less than 40 feet. In the middle of the stope its greatest width is over 70 feet. Barton's shaft is sunk on this bunch of ore, and the present 74 and 90 fathom level stopes are opened on it. In the southern ground the lode forms two branches, developing two separate deposits. The deposit on the eastern branch commences at a distance of 130 feet southward from the middle ore body, and that on the western branch at 170 feet. The ore in the eastern branch is 68 feet long by an average of 25 feet wide, and that on the western branch 68 feet long by 10 feet wide in the bottom of the 54-fathom level. These masses of ore have not been touched below the 54-fathom level. In development work the 90-fathom level drive north has been extended to a distance of 100 feet from Barton's shaft, and the 90-fathom level, south 50 feet; both faces in ore ground. The 70-fathom level drive north is now distant from Barton's shaft 310 feet, and the south drive 250 feet. The north drive is opened beyond the extent of the back stope 83 feet into the less productive ground situated between the deposits of ore, the lode in the face of the drive being 4 feet wide. The south drive at this level, since leaving the middle deposit, has also been driven in unproductive ground, but there are at present indications of ore in the end. *East Lode.*—At the 34-fathom level, a cross-cut, put out eastward from the Main Lode, near Becker's shaft, intersected, in a short distance, the western wall of the separate formation known as the East Lode. This lode has been driven across over 30 feet, the ore obtained from it being taken to the smelters. It does not present a solid sulphide mass, such as is shown by the main lode, but its structure is of a more laminated character, and its composition slaty, resembling the country rock. The layers of ground in the lode dip with its underlay, and are intercalated with seams of ore, and seams of quartz. What is probably the same lode was discovered some years ago in the 54-fathom level, eastward from Becker's shaft, where its width was found to be 21 feet, and where its composition is very much the same as that of the 34-fathom level lode, except that the veins of ore in the slaty matrix take a more defined sulphide form. In addition to the ore ground developed in the main lode, there is the ore in the east lode already referred to, and there are, within 300 feet to the east, two parallel mineral outcrops, which afford very promising scope for exploration.' "

Twenty-ninth General Meeting of Shareholders, August 26th, 1890.—Memo. of percentages of ore smelted at Cobar to June 30th, 1890 :—

| Half-year ended. | Ore. | | Copper. | Percentage. |
|---|---|---|---|---|
| 31 Dec., 1876 ... ... | 1,458 tons, | equal to | 174 tons ... ... | 11·93 |
| 30 June, 1877 ... ... | 2,350 ,, | ,, | 255 ,, ... ... | 10·85 |
| 31 Dec., 1877 ... ... | 2,530 ,, | ,, | 268 ,, ... ... | 10·59 |
| 30 June, 1878 ... ... | 3,651 ,, | ,, | 600 ,, ... ... | 16·43 |
| 31 Dec., 1878 ... ... | 4,738 ,, | ,, | 857 ,, ... ... | 18·08 |
| 30 June, 1879 ... ... | 5,610 ,, | ,, | 876 ,, ... ... | 15·61 |
| 31 Dec., 1879 ... ... | 7,005 ,, | ,, | 1,015 ,, ... ... | 14·48 |
| 30 June, 1880 ... ... | 8,334 ,, | ,, | 1,181 ,, ... ... | 14·70 |
| 31 Dec., 1880 ... ... | 11,890 ,, | ,, | 1,388 ,, ... ... | 11·67 |
| 30 June, 1881 ... ... | 9,930 ,, | ,, | 1,163 ,, ... ... | 11·71 |
| 31 Dec., 1881 .. ... | 11,622 ,, | ,, | 1,405 ,, ... .. | 12·08 |
| 30 June, 1882 ... ... | 5,882 ,, | ,, | 942 ,, ... ... | 16·00 |
| 31 Dec., 1882 ... ... | 5,820 ,, | ,, | 863 ,, ... ... | 14·82 |
| 30 June, 1883 ... ... | 6,772 ,, | ,, | 955 ,, ... ... | 14·10 |
| 31 Dec., 1883 ... ... | 11,324 ,, | ,, | 1,460 ,, ... ... | 12·89 |
| 30 June, 1884 ... ... | 11,876 ,, | ,, | 1,361 ,, ... ... | 11·46 |
| 31 Dec., 1884 ... ... | 12,003 ,, | ,, | 1,408 ,, ... ... | 11·73 |
| 30 June, 1885 ... ... | 11,558 ,, | ,, | 1,064 ,, ... ... | 9·20 |
| 31 Dec., 1885 ... ... | 12,000 ,, | ,, | 1,066 ,, ... ... | 8·88 |
| 30 June, 1886 ... ... | 14,000 ,, | ,, | 1,093 ,, ... ... | 7·80 |
| 31 Dec., 1886 ... .. | 11,887 ,, | ,, | 951 ,, ... ... | 8·04 |
| 30 June, 1887 ... ... | 10,840 ,, | ,, | 888 ,, ... ... | 8·01 |
| 4 Feb., 1888 ... ... | 9,000 ,, | ,, | 705 ,, ... ... | 7·83 |
| 30 June, 1888 ... ... | 5,500 ,, | ,, | 416 ,, ... ... | 7·56 |
| 31 Dec., 1888 ... ... | 7,425 ,, | ,, | 589 ,, ... ... | 7·09 |
| 3 Aug., 1889 ... ... | 8,177 ,, | ,, | 667¾ ,, ... ... | 8·15 |
| Totals ... ... | 213,182 tons | | 23,610¾ tons | Average 11·07 |

Extract from a report by L. Janin, jun., Mining Engineer and Metallurgist, published in the prospectus of the Cobar Chesney Copper and Gold-mining Company (Limited), 1897, p. 14 :—

"In regard to the grade of copper-ore that can be treated profitably at Cobar, the following figures may prove instructive. They are the yields of the Great Cobar Copper Mine, worked by tributors :—

| | Tons smelted. | Tons of copper. | Per cent. of copper. | Oz. of gold. | dwt. per ton. | Oz. of silver. | Oz. per ton. |
|---|---|---|---|---|---|---|---|
| Jan. to June, 1895 ... | 16,966 | 711 | 4·19 | 3,276 | 3·8 | 6,896 | 0·4 |
| July to Dec., ,, ... | 21,631 | 972 | 4·5 | 3,756 | 3·4 | 7,726 | 0·3 |
| Jan. to June, 1896 ... | 26,948 | 1,268 | 4·3 | 4,918 | 3·6 | 13,626 | 0·5 |
| July to Dec., 1896 ... | 36,689 | 1,392 | 3·9 | 5,889 | 3·3 | 14,908 | 0·4 |
| Jan. to June, 1897 ... | 33,400 | 1,307 | 3·8 | 6,525 | 3·8 | 15,516 | 0·4 |

"It will be noted that in the past year, approximately 69,000 tons of ore were smelted for approximately 2,700 tons of copper. The gross profits for that period are estimated at £92,000. It will be noticed that the average assay for gold in the Chesney is, approximately, the same as in the Cobar Copper Mine."

MEMO. of Dividends paid to 28th December, 1898.

| | s. | d. | | s. | d. |
|---|---|---|---|---|---|
| March 1st, 1880—1st, of ... | 2 | 6 | March 7th, 1895—17th, of ... | 0 | 6 |
| May 1st ,, —2nd, ,, ... | 2 | 6 | July 24th, ,, —18th, ,, ... | 0 | 6 |
| July 14th ,, —3rd, ,, ... | 2 | 6 | Oct. 16th, ,, —19th, ,, ... | 0 | 6 |
| Sept. 1st, ,, —4th, ,, ... | 2 | 6 | Jan. 22nd, 1896 —20th, ,, ... | 0 | 6 |
| Mar. 14th, 1881—5th, ,, ... | 2 | 6 | April 15th, ,, —21st, ,, ... | 0 | 6 |
| June 3rd, ,, —6th, ,, ... | 2 | 6 | July 15th, ,, —22nd, ,, ... | 0 | 6 |
| Sept. 5th, ,, —7th, ,, ... | 2 | 6 | Aug. 26th, ,, —23rd, ,, ... | 0 | 6 |
| Mar. 1st, 1883 —8th, ,, ... | 2 | 6 | Nov. 25th, ,, —24th, ,, ... | 0 | 9 |
| April 2nd, ,, —9th, ,, ... | 2 | 6 | March 3rd, 1897—25th, ,, ... | 1 | 0 |
| April 16th, ,, —10th, ,, ... | 2 | 6 | June 9th, ,, —26th, ,, ... | 0 | 9 |
| May 3rd, ,, —11th, ,, ... | 2 | 6 | Sept. 8th, ,, —27th, ,, ... | 0 | 9 |
| June 6th, ,, —12th, ,, ... | 2 | 6 | Dec. 22nd, ,, —28th, ,, ... | 0 | 9 |
| August 28th ,, —13th, ,, ... | 2 | 6 | March 31st, 1898—29th, ,, ... | 1 | 0 |
| Nov. 30th, ,, —14th, ,, ... | 2 | 6 | June 29th, ,, —30th, ,, ... | 1 | 0 |
| June 6th, 1884 —15th, ,, ... | 2 | 6 | Sept. 21st, ,, —31st, ,, ... | 1 | 0 |
| Dec. 31st, 1888 —16th, ,, ... | 1 | 0 | Dec. 28th, ,, —32nd, ,, ... | 1 | 6 |

making a total of £202,000 paid in dividends since the formation of the Company, or at the rate of £2 10s. 6d. per share.

*Nymagee Copper Mine.*—The Nymagee deposit, like that of Cobar, consists essentially of a bedded lode (though in places it appears to cut across the strata), and its proprietors have had to contend against the same difficulties which have handicapped the copper-mining industry at Cobar, for Nymagee is also situated in an arid portion of the Western District. It is distant about forty miles in a southerly direction from the Hermidale Railway Station, between Nyngan and Cobar. The Nymagee Mine was first opened in the year 1880, and shortly afterwards, Mr. Lamont Young, Geological Surveyor, described the deposit in a report, from which the following extracts are taken :—"The slate rocks adjoining the copper deposits are of a sandy character, and have a strike of N. 24° W., dipping to the S.W. at an angle of 68°. At Nymagee mine there appear to be two lodes. The main lode has a strike of N. 17° 30′ W., and is nearly vertical ; three shafts have been sunk upon it at distances of 276 feet apart. To the east of the middle shaft (No. 3) may be seen the outcrop of a branch lode, having a strike of N. 9° E., and which, as yet, remains unexplored. In the three shafts sunk to 120, 55, and 80 feet, respectively, the width and composition of the lode at these levels, is: At (No. 1) 120 feet, a lode 8 feet wide, composed almost entirely of yellow sulphide mixed with black oxide of copper ; at (No. 3) 55 feet, the lode is 8½ feet wide, and is composed of earthy carbonates, grey sulphides, and red oxide of copper, mixed with decomposed slate, and brown iron ore. At No. 2 shaft (80 feet) the lode is 5½ feet wide as yet, but the whole width has not been exposed; it contains large masses of brown iron ore, and grey sulphide and red oxide of copper.

"The second lode on this property is called the 'East Lode' ; it has a strike of N. 18° W., and is composed of argillaceous matter, earthy carbonates, red oxide, and grey and yellow sulphides of copper, the latter only in patches."

The main shaft has now a total depth of 734 feet, and the deepest level is at 720 feet. Here the lode is composed of massive sulphides, and is said to be thirty feet wide, and to contain about 2 per cent. of copper, though a couple of narrow seams of good ore occur in it.

The mine was originally worked by a company with a nominal capital of £80,000, in 80,000 shares of £1 each, and between the years 1883 and 1889 it paid fifteen dividends, amounting in the aggregate to £94,000, or equal to £1 3s. 6d. per share. In 1893, mining operations were stopped owing to the low price of copper, but in the following year the mine was again opened. In 1895 it was worked on tribute, and in 1896 it was purchased by the Cobar Mining Syndicate, who introduced a blast furnace for reducing, and subsequently started pyritic smelting. The Nymagee copper has always been of good quality; it contains a small proportion of silver, but no gold. The average length of the main sulphide ore body, where exploited, has been about 250 feet ; its average width from fifteen to twenty feet, and its average yield about 10 per cent. of copper.

RETURN of the yearly outputs and progress of the Nymagee Copper Mine, compiled from the half-yearly reports of the Nymagee Copper Mining Company (Limited) and the Annual Reports of the Department of Mines and Agriculture, by J. E. Carne.

| Year. | Ore raised. | Ore smelted. | Copper reduced. | Percentage. | Value. | Deepest shaft. | Deepest level. | Width of lode. | Men employed. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| | tons. | tons. | tons. | | £ | ft. | ft. | ft. | | |
| 1881.. | 6,571 | 6,053 | 859 | 13·61 | 60,000 | 240 | 240 | 15–25 | | Output since 1880. |
| 1882.. | 7,677 | 6,618 | 1,144 | 17·13 | 80,000 | 270 | ,, | 2–30 | 500 | |
| 1883.. | 10,568 | 10,236 | 1,714 | 16·75 | 96,000 | 390 | 310 | 3–18 | | |
| 1884.. | 14,748 | 14,743 | 2,207 | 14·95 | .... | ,, | ,, | 4–12 | | |
| 1885.. | 16,310 | 15,773 | 1,791 | 11·35 | 80,000 | 528 | 430 | ,, | 350 | 52,000 tons of wood consumed annually. |
| 1886.. | 14,372 | 14,449 | 1,468 | 10·15 | 60,967 | ,, | 516 | ,, | 300 | |
| 1887.. | 9,861 | 10,739 | 1,036 | 9·64 | 48,107 | 628 | 618 | 10–25 | 350 | |
| 1888.. | 12,472 | 12,826 | 1,297 | 10·11 | 91,000 | 734 | ,, | 8–20 | 250 | Copper boom year. |
| 1889.. | 8,585 | 8,704 | 836 | 9·60 | 39,000 | ,, | 720 | ,, | ,, | Collapse of boom. |
| 1890.. | 7,954 | 8,098 | 792 | 9·78 | 43,868 | ,, | ,, | ,, | ,, | |
| 1891.. | 9,482 | 9,537 | 916 | 9·60 | 45,050 | ,, | ,, | .... | | |
| 1892.. | 6,238 | .... | 697 | 11·01 | 31,600 | ,, | ,, | .... | | |
| 1893.. | .... | .... | .... | .... | .... | ,, | ,, | .... | .. | Mine closed. |
| 1894.. | 1,638 | .... | 148 | 8·76 | 5,940 | ,, | ,, | .... | 120 | |
| 1895.. | 5,845 | .... | 485 | 8·29 | 21,825 | ,, | ,, | .... | 150 | Worked on tribute. |
| 1896.. | 3,249 | .... | 380 | 11·08 | 17,948 | ,, | ,, | .... | | Mine purchased by Great Cobar Mining Syndicate. |

*The Girilambone Copper Mine* is situated on the western railway line at a distance of 405 miles from Sydney, and was first opened in the year 1880 by Hartman and Campbell, the discoverers of the Great Cobar Mine. The Girilambone Mine was closed down from 1885 and 1893, and also during the years 1895 and 1896. Towards the end of the latter year it was floated into a company named the Girilambone Copper Mining Company (Limited), and mining operations have been carried on ever since.

The country rocks consist of schistose slates, sandstones, and quartzites, and the former contain numerous cupriferous quartz veins, together with segregations of copper ore. The oxidised ores, consisting of blue and green carbonate, and red oxide, extend to a depth of about 200 feet. Between this zone and that of the unaltered sulphides, loose earthly melaconite, or black oxide of copper, occurs. Although the deposit is of considerable width, as much as forty feet in places, the copper ores, both in the oxidised and in the sulphide zones, are very closely associated with quartz, and herein lies the principal difficulty with which the Company has to contend, for it necessitates extensive concentration under conditions which lead to a considerable loss (in waste) of copper contents. The main shaft has reached a depth of 544 feet, and the deepest working level is at 300 feet, though another level is being driven at a depth of 520 feet, and this is expected to develop a considerable reserve of sulphide ores.

Owing to the siliceous character of the Girilambone ores, pyritic smelting is not practicable, and reverberatory furnaces are therefore used. The present plant consists of five reducing furnaces, and one for refining. The copper produced is of extremely good quality; its assay value being 99·95 per cent. The following extract shows the character and proportions of the different grades of ore raised, and the results of dressing and concentrating operations during the half-year ending 30th June, 1898:—

*Ore Account.*

| | Tons. | | Per cent. | | Copper contents. Tons. | cwt. | Tons. | cwt. | Tons. | cwt. |
|---|---|---|---|---|---|---|---|---|---|---|
| *Ore Raised and Jigged—* | | | | | | | | | | |
| Carbonates ... | 2,579 | @ | 4·6 | = | 118 | 12 | 283 | 12 | 428 | 19 |
| Sulphides ... | 3,263 | @ | 3·1 | = | 101 | 3 | | | | |
| Oxides ... ... | 953 | @ | 6·7 | = | 63 | 17 | | | | |
| | 6,795 | | | | | | | | | |
| *Screened Ore—* | | | | | | | | | | |
| Carbonates ... | 1,109 | @ | 13·0 | = | 144 | 3 | 145 | 7 | | |
| Sulphides ... | 44 | @ | 2·8 | = | 1 | 4 | | | | |
| | 7,948 | | | | | | | | | |

*Producing.*

| | Tons. | | Per cent. | | Tons. | cwt. | Tons. | cwt. |
|---|---|---|---|---|---|---|---|---|
| *Jigged Ore—* | | | | | | | | |
| Carbonates, No. 1 | 464 | @ | 10·9 | = | 50 | 11 | 139 | 10 |
| Sulphides, No. 1 | 706 | @ | 6·5 | = | 45 | 17 | | |
| Oxides, No. 1 ... | 273 | @ | 15·8 | = | 43 | 2 | | |
| ,, No. 2 ... | 859 | @ | 3·5 | = | 30 | 0 | 101 | 8 |
| ,, No. 3 ... | 64 | @ | 4·0 | = | 2 | 11 | | |
| Tailings... ... | 2,994 | @ | 2·3 | = | 68 | 17 | | |
| Slimes and waste | 1,435 | | ... | | ... | say | 42 | 14 |
| | | | | | | | 283 | 12 |
| *Screened Ore—* | | | | | | | | |
| Carbonates ... | 1,109 | @ | 13·0 | = | 144 | 3 | 145 | 7 |
| Sulphides ... | 44 | @ | 1·4 | = | 1 | 4 | | |
| | | | | | | | 428 | 19 |

In the same half-yearly report (ending 30th June, 1898) the following statement is given of the smelting operations of the Company :—

*Ore Smelted.*

| | Tons. | | Per cent. | | Tons. | cwt. | Tons. | cwt. |
|---|---|---|---|---|---|---|---|---|
| *Concentrates—* | | | | | | | | |
| No. 1 Carbonates | 464 | @ | 10·9 | = | 50 | 11 | | |
| No. 1 Sulphides ... | 706 | @ | 6·5 | = | 45 | 17 | | |
| No. 1 Oxides ... | 273 | @ | 15·8 | = | 43 | 2 | 150 | 4 |
| *Old Stock—* | | | | | | | | |
| No. 1 Carbonates... | 107 | @ | 10·1 | = | 10 | 14 | | |
| *Screened Ore—* | | | | | | | | |
| Carbonates . | 1,109 | @ | 13·0 | = | 144 | 3 | | |
| Sulphides ... ... | 44 | @ | 2·8 | = | 1 | 4 | 145 | 7 |
| | | | | | | | 295 | 11 |

*Copper Won—*

| | Tons. | cwt. | Tons. | cwt. | qrs. | lb. |
|---|---|---|---|---|---|---|
| Despatched ... ... ... ... ... | | | 153 | 4 | 2 | 1 |
| Balance 1st July ... ... | 64 | 0 | | | | |
| Less balance, 31st December | 10 | 10 | 53 | 10 | 0 | 0 |
| | | | 206 | 14 | 2 | 1 |

*New Mount Hope Copper Mine.*—This is another instance of a bedded deposit and it occurs in very similar country to the mines which have already been described. Mount Hope is situated about 120 miles to the south-west of Nyngan Railway Station. The deposit was discovered in the year 1878, and in 1881 it was floated as the New Mount Hope Copper Mining Company, though there are no records of the output of the mine before 1883. The lode occurs in ferruginous slates and sandstones, striking about N. 10° E.; these rocks are much indurated by silicification, and are intersected by numerous quartz veins. The ore, like that of Girilambone, consists chiefly of impregnations and segregations, and in consequence of this it requires concentration before being ready for smelting. The oxidised zone reached from the surface to depths of 170 to 270 feet, and here the ores consisted of earthy blue and green carbonates, and red oxide of copper, with some grey sulphide. Some beautiful large octahedral crystals of cuprite (red oxide of copper) were obtained from the upper levels, and some of the carbonate ore is in the form of a very characteristic stockwork, in which narrow veinlets of azurite and malachite intersect one another in various directions. No bodies of massive sulphide ore have yet been discovered, although it seems quite probable that further prospecting operations might result in their development.

The sulphide ores are of high grade, but they are rather sparingly disseminated through the siliceous matrix, and they are wanting in iron sulphides, which is a great disadvantage in view of the character of the gangue. It becomes necessary therefore to procure iron ores from some distance as a flux for the ore in the furnaces. A considerable quantity of iron ore was obtained from Mount Allen, about twelve miles distant, but this ore was eventually found to contain gold in considerable quantity, and it has, for some years past, been worked for that metal.

Statement of the yearly outputs and progress of the New Mount Hope Copper Mine. Compiled by J. E. CARNE.

| Year. | Ore raised. | Copper reduced. | Value. | Deepest shaft. | Deepest level. | Width of lode. | Number of furnaces. | Value of plant. | Men employed. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons. | Tons. | £ | Feet. | Feet. | Feet. | | £ | | |
| 1883 | 2,088 | 431 | 22,000 | 268 | 150 | ? | 4 | 7,612 | 200 | |
| 1884 | 6,194 | 1,258 | 54,000 | 340 | 270 | 10-50 | (Reverberatory) | .. | 236 | |
| 1885 | 3,795 | 635 | .... | .. | . | .. | ...... | .. | .. | Work suspended. |
| 1886 | .... | .. | .... | | | .. | ...... | .. | .. | A few men employed developing. |
| 1887 | .... | .. | .... | . | .. | .. | ...... | .. | .. | Steps being taken to re-open mine. |
| 1888 | 1,187 | 137 | 8,900 | | .. | .. | ...... | .. | .. | £4,800 worth of ore raised. |
| 1889 | 1,870 | 260 | 10,400 | .. | .. | .. | ...... | .. | .. | |
| 1890 | 1,143 | 218 | 10,900 | 340 | 340 | 68 | ...... | 700 | 46 | Worked on tribute. |
| 1891 | 1,094 | 208$\frac{1}{4}$ | 9,158 | 340 | 340 | 58 | ...... | .. | 36 | ,, |
| 1892 | ? | 190 | 6,283 | 340 | 340 | .. | ...... | .. | 40 | ,, |
| 1893 | ? | ? | 6,501 | 340 | 340 | .. | ...... | .. | 40 | ,, |
| 1894 | 892 | 135 | 4,054 | 340 | 340 | .. | ...... | .. | 36 | ,, |
| 1895 | 858 | 143$\frac{1}{3}$ | 5,456 | 340 | 340 | 58 | ...... | .. | 38 | ,, |
| 1896 | 1,092 | 141$\frac{1}{2}$ | 5,660 | 340 | 340 | .. | ...... | | 36 | ,, |
| 1897 | 734 | ? | 5,340 | 340 | 340 | .. | ...... | .. | 40 | ,, |
| 1898 | 992 | 134$\frac{2}{3}$ | 6,845 | 360 | 340 | .. | ...... | .. | .. | |

The total output of the mine from 30th April, 1881, to 31st December, 1898, amounts to 5,070 tons of refined copper.

*The Lake George Copper Mines* are situated at Captain's Flat, about 25 miles south of Bungendore, a station on the Cooma railway line, in country which differs in almost every respect from that in which the previously-described copper mines occur. The site of the Lake George Mines has an elevation of about 2,700 feet above sea-level, and the surrounding district consists of well-watered forest land. These mines were first opened in the year 1882, when the outcrops of the lodes, consisting of auriferous gossan, were worked for gold. Two years later (1884) it was announced that the gossan was underlaid by a large low-grade copper lode, and in 1885 blast-furnace treatment was introduced. The lodes were at first held by two companies, one of which worked the Koh-i-noor Mine, while the other owned the Commodore Vanderbilt; but in the year 1894 the two mines were amalgamated, and became the property of the Lake George United Mining and Smelting Company. In 1896 the Company was reformed, with the addition of fresh capital, under the title of the Lake George Mines (Limited).

Messrs. J. B. Jaquet and J. A. Watt, Geological Surveyors, reported on the deposits in 1897, and the following extract gives their views upon the occurrence:—"The dominant formations at Captain's Flat are Silurian slates, breccias, &c., which have a meridional strike, and, for the most part, nearly vertical dip. Upon the western side of the township flat there is a slight western dip (? underlie), and at the Vanderbilt Mine, which is situated upon the eastern side of the flat, we found an eastern dip. So an anticline would seem to have stretched across the flat at one time, and the Vanderbilt Lode upon one hand, and the Koh-i-noor and Commodore Lode on the other, would seem to be on the same geological horizon."

"The lodes wherever observed by us are clearly conformable with the bedding planes of the country rock. . . . . Portions of the lode exhibit a perfect bedded structure, and without doubt represent country rock, which has been slowly replaced by ore *in situ*. In many places no distinct walls occur, and compact ore may be seen, passing by insensible gradations into country rock slightly impregnated with iron pyrites."

"The Commodore Shaft—now called Keating's Section—is distant 3,300 feet from the Koh-i-noor Shaft—now Elliott's Section—and between the two there is 1,500 feet of unproved ground. The lode in Elliott's Section, to the 400 feet level, varies from twenty-two to thirty feet in thickness. In Keating's Section it reached a thickness of forty feet. The unaltered sulphide ore consists essentially of a compact, fine-grained mixture of iron pyrites, galena, and zincblende, with a small quantity of copper pyrites, and a quartzose aluminous gangue. Upon the footwall side of the pyrites lode in Elliott's Section, a considerable quantity of barytes is, in places, associated with the ore. Between the unaltered primary ore and the gossan which caps the lode, there is present a zone of partially oxidised and enriched sulphides, which differ noticeably from those below in containing black oxide of copper (tenorite), and in being, on the whole, slightly more friable. The upper portions of the gossan have been almost entirely robbed of their copper, lead, and zinc contents by percolating waters, and the enrichment in copper of the unaltered sulphides is probably due to a portion of the metal having been re-deposited as black oxide below."

An analysis (by Mr. H. P. White, F.C.S., in the Laboratory of the Department of Mines) of a representative sample taken by Messrs. Jaquet and Watt from the various working faces of the great pyrites lode at the 400-feet level, gave the following results:—

| | |
|---|---|
| Moisture at 100° C. | 0·10 |
| Combined water | 0·65 |
| Insoluble in acids (gangue) | 23·70 |
| Metallic iron | 17·75 |
| ,, zinc | 14·50 |
| ,, lead | 8·04 |
| ,, copper | 1·11 |
| Sulphate of lead | 0·32 |
| Alumina | 1·38 |
| Lime | 0·40 |
| Magnesia | 0·65 |
| Sulphur trioxide | 0·25 |
| Carbonic acid | 2·08 |
| Phosphoric acid | 0·57 |
| Sulphur | 27·97 |
| Oxygen, and undetermined | 0·53 |
| | 100·00 |

NOTE.—91·35 % of the gangue consists of silica, the remainder containing alumina, magnesia, and alkalies.

The following statement of the output of the Lake George Mines (Limited), was supplied by Mr. R. N. Kirk, Sydney Agent of the Company:—

| Date. | Ore smelted. | Matte produced. | Gold in matte. | Silver in matte. | Copper in matte. | Gold per ton of ore. | Silver per ton of ore. | Copper per cent. | Cost of production per ton of ore. |
|---|---|---|---|---|---|---|---|---|---|
| | tons. | tons. | ounces. | ounces. | tons. | ounces. | ounces. | | shillings. |
| From commencement of operations to stoppage in Sept., 1898. | 79,010·4 | 2,673·62 | 5,158·12 | 190,505·08 | 885·69 | 0·065 | 2·411 | 1·12 | .... |
| From recommencement of work on 26 Nov. to 31 Dec., 1898. | 6,351·5 | 295·56 | 575·67 | 15,954·58 | 92·60 | 0·099 | 2·511 | 1·457 | ...... |
| Jan., 1899 ...... | 5,312·56 | 274·20 | 452·68 | 13,761·86 | 76·86 | 0·085 | 2·590 | 1·446 | 14·78* |
| Feb., 1899 ...... | 5,420·18 | 291·18 | 369·63 | 14,712·55 | 86·93 | 0·068 | 2·714 | 1·603 | 14·65* |

* Total cost of mining, handling, smelting (inclusive of all fluxes and fuels) and general mine expenses.

*The Gulf Creek Copper Mine.*—One of the most interesting copper-mines in New South Wales at the present time is known as *The Gulf Creek* (*Limited*), and is situated in the parish of Capel, county of Murchison, about ten miles in an easterly direction from Cobbadah. It was formerly known as the Cornish Copper-mine, but was purchased in 1899 by Mr. W. H. Trewenack, and resold by him to the Gulf Creek (Limited). The property consists of 250 acres, comprised in mineral lease portions 1, 2, 17, and 50; an additional area of 60 acres has recently been applied for.

The lode originally worked by the Cornish Company was about three feet eight inches in average width, and was prospected by an inclined shaft to a depth of 167 feet, while drives were put in at depths of 48, 98, and 148 feet. This shaft is situated close to the bank of the creek, and there is, consequently, rising ground on both sides of it along the course of the lode.

After securing an option to purchase the mine, Mr. Trewenack put in a cross-cut in a south-westerly direction at the 48-ft. level, and at a distance of 31 feet from the Cornish lode, he intersected a lens of sulphide ore nine feet in width, and said to contain 7 per cent. of copper. The *length* of this ore body has not yet been proved. On continuing the cross-cut for a further distance of 10 feet another ore body was met with, which, at this point proved to be 19 feet 6 inches in width. A drive was then put in along this ore-body in a south-easterly direction, and this proved it to be lenticular in form, thinning out to a point at a distance of 350 feet south-east from where it was first intersected in the cross-cut. Several other cross-cuts were then put in from the drive, and these have shown that the ore body has an average width of 25 feet, with a length of 350 feet, its maximum width

*Photographed by E. F. Pittman.*

THE GULF CREEK (LIMITED) COPPER SMELTING WORKS NEAR COBBADAH.

being 38 feet. A stope has been taken out for the entire length (350 feet) and Mr. Trewenack states that the whole of the ore extracted from this has averaged 14 per cent. of copper. (It may be mentioned that what appeared to be a typical specimen of the ore recently taken at random from the heap was assayed in the Laboratory of the Department of Mines, and yielded 4·88 per cent. of copper.) The north-western extremity of this fine lens of ore has not yet been reached, but north-west of the cross-cut it has become poorer in copper contents, its average, according to Mr. Trewenack, being about 6 per cent. The strike or bearing of the lens of ore is N.W. by W., and its dip is N.E. by N, at an inclination of 54°. It is interbedded with the country rocks, which consists of indurated claystones of Carboniferous age, and these have been intruded by dykes of serpentine. One of these dykes extends along close to the hanging wall of the old Cornish lode, and another has been met with in a crosscut about 30 feet from the footwall of the big lode. The effect of the dykes upon the claystones has been to convert them into jasperoid quartzites; and on the south-western side of the ore bodies, and extending parallel with them, well-defined beds of these quartzites are seen outcropping.

On both the hanging wall and foot wall of the large ore body there is a dig or casing, a foot or more in width, of very white siliceous clay. A sample of this clay has been tested in the Laboratory of the Department of Mines, with the object of ascertaining its suitability for the manufacture of fire bricks. The following in the Analyst's report:—"Two bricks were made from this material, one with the addition of 25 per cent. of clean sand, and the other with the material only. The bricks were carefully dried and burnt in a muffle furnace for two hours, and afterwards placed in a covered crucible and submitted to a severe heat in the coke assay furnaces for two hours. No fusion had taken place, the sharp edges being retained. The bricks are very light." The sample was also found to contain 1·96 per cent. of copper. The occurrence of this dig greatly facilitates the working of the deposit, and the contract price for winning the ore (including timbering), and delivering it at the moth of the level, varies from only 2s. 9d. to 4s. per ton.

Three cross-cuts have been driven in a north-east direction from the hanging wall of the ore body, and it is stated by the manager that the rocks (claystones) penetrated by these for a width of at least twenty-five feet contain on an average three per cent. of copper, which occurs in the form of native copper and cuprite (red oxide).

The large sulphide ore body has not yet been tested below the 48 feet level, and its quality above the first stope is also unknown at present. A wide gossan formation which can be seen in one bank of the creek is evidently the cap of the ore body, but it shows no stains of copper carbonates. Owing to the south-eastern end of the lens of ore being situated under high ground there are probably about 100 feet of backs above the drive at this point.

The ore in the mine consists essentially of massive iron pyrites which has been permeated by copper glance (chalcocite) of an impalpable character, so that the whole material has a black appearance, and it is only by the aid of a lens that the metallic lustre of the iron sulphide can be distinguished in the mass. It is evident that rapid decomposition of the ore is in progress as much heat is being envolved, and in some of the stopes a man can scarcely keep his hand upon the ore; sulphate of copper is also showing freely in the joints and along the walls as a result of the oxidation. It is probable that some difficulty may be experienced in connection with this heating, as it will have a tendency to cause fires in the mines. The Gulf Creek deposits appear to possess many points of resemblance, both in their mode of occurrence and in the composition of the ore, to those of Rio Tinto in Spain; the latter, however, contain only about 2½ per cent. of copper, and it is probable that the Gulf Creek ore will become poorer as greater depth is attained. There is every reason to expect that other parallel ore deposits of a similar character will be found as prospecting operations are carried out in the neighbourhood of the serpentine dykes, and that copper-mining will become a permanent industry in this district.

*Treatment of the Ore.*—The broken ore is thrown upon a grizzly which separates it into "roughs" and "fines." The former are roasted in open heaps while the latter are treated in a reverberatory calcining furnace. The roasted ore is then mixed with a certain proportion of "green" or unroasted ore in a water-jacket blast furnace; the resulting matte contains about 40 per cent. of copper.

The furnace charges are as follow:—

| | | | |
|---|---|---|---|
| Roasted ore | = | 336 | lb. |
| "Green" fines | = | 112 | ,, |
| Limestone | = | 28 | ,, |
| Quartzite | = | 28 | ,, |
| Coke | = | 35–40 | ,, |
| Slag | = | 84 | ,, |

The ore contains a very small proportion of silica, and appears to be eminently suited for pyritic smelting. It is the intention of the company to adopt this method of treatment as soon as possible, and the necessary furnaces for smelting and refining are now in course of construction; it is intended to commence with a furnace having a capacity of 80 tons.

### *Distribution of Copper Ores.*

The following is a list of the localities from which samples of copper ores have been forwarded to the Department of Mines for assay:—

Abercrombie.
Adaminaby.
Adelong, five miles from.
Apsley, near Bathurst.
Armidale.
Ashford.
Back Creek.
Badger River, Monaro District.
Ballimore.
Bark Hut, Monaro.
Barraba.
Barrier Range.

Bathurst, near.
Belara.
Bennberg, near
Bermagui River.
Binalong.
Bindogandra, twelve miles from.
Bingara.
Bingara, three miles north of.
Black Range, fourteen miles east of (Overflow District).
Blayney.
Blyth, Parish of, County of Clarke.
Bobadah, three miles from Overflow Silver Mine.
Bobby Whitlow, Bingara.
Boggy Camp.
Bolivia, New England.
Bombala.
Bombolee, Tumut.
Bonshaw, three miles from.
Bonshaw, fifteen miles from.
Bookham, ten miles from.
Boonoo-Boonoo.
Boorolong.
Borah Creek, near Inverell.
Boree, Parish of.
Borenore, near.
Boro.
Bourke, near.
Braidwood District.
Bredbo.
Brewongle.
Broken Hill.
Brungle.
Bulga Mountain, near Orange.
Bungendore.
Bungendore, six miles west of.
Bungendore, nine miles from.
Bungonia.
Bungonia, twelve miles from.
Bunnamagoo.
Bucca Creek.
Buckley's Crossing.
Burley Jacky Mine, near Woodstock.
Burnt Yards.
Burra Burra.
Burraga.
Burraga, fourteen miles from.
Burraga, South.
Burrowa.
Bushy Hill, Cooma.
Byng, near.
Bywong.
Cangi.
Canoblas, Orange.
Canowindra.
Capertee.
Capertee, four and a half miles west of.
Captain's Flat, near Queanbeyan.
Carcoar, near.
Cargo.
Carma, thirty miles south of.
Carr's Creek.
Chandler, Parish of, County of Clarke
Chandler River, Hillgrove District.
Clarence River.
Cleifden, County of Bathurst.
Cobar.
Cobborah.
Cockburn (Burta Station).
Colo Creek, near Newbridge.
Condobolin.
Condobolin, Walker's Hill.
Coolah (Pine Ridge).
Cooma, near.
Cooma, five miles from.
Cootamundra, five miles from.
Cootamundra, eight miles north-west of.
Cope's Creek.
Copper Hill, Molong.
Corona.
Costigan's Mount.
Cow Flat.
Cowra.
Cowra, twenty miles east of.
Crow Mountain, near.
Cryer's Arms Creek, near Bungonia.
Cudal, sixteen miles from.
Cudgegong.
Cullen Bullen.
Cullen's Creek, Rivertree.
Cumnock.
Curracabark.
Currawang, Parish of Granville, County of Wellesley.
Dandaloo, near.
Darby's Run, near Tingha.
Daviesville, near Wellington.
Deepwater, near.
Denison Town.
Drake.
Dubbo, near.
Dungowan.
Eden.
Elsmore (Newstead Mine).
Emmaville.
Essington, near Rockley.
Eugowra.
Fairfield.
Fiery Creek.
Fireflower Creek.
Forbes.

Frogmore.
Gilgunnia.
Ginninderra.
Girilambone.
Glanmire.
Glenborne, O'Connell.
Glen Innes.
Gloucester (Hook's Reef).
Goba Creek, near, ten miles north of Burrowa.
Gooda Creek, near Yass.
Goodrich, between Orange and Wellington.
Goolagong.
Gordon.
Goulburn, near.
Grafton.
Grassmere.
Green Swamp, near Bathurst.
Gulgong.
Gulgong, three miles from.
Gumble.
Gundabooka Run, near Bourke.
Gundagai.
Gundagai, twelve miles from.
Guyra.

Hall.
Hampton (Bull's Creek).
Hastings River.
Hill End.
Hillman's Tank, Nymagee.
Holt-Sutherland.

Inverary, Parish of, near Bungonia.
Inverell, near.
Ironbarks.

Jacqua Creek, Shoalhaven.
Jaunta, near Shooter's Hill.
Jenolan Caves, 2½ miles from.
Jervis Bay, south-east from.
Jinderbyne.
Jingellic.
Junee Reefs.

Kadumble Range, Wellington.
Kallara.
Kempfield, near Trunkey.
Kiama, near.
Kiandra, twelve miles from.
King's Creek, near, County of Westmoreland.
Kooningberry Gap.
Kooningberry Gap, nine miles north-west of.

Larry's Flat, near.
Leadville.
Lewis Ponds, near Orange.
Liliwa, Cudgegong.
Little River.
Lowther, twelve miles from Bowenfels.
Lue, 1½ mile from.
Lucknow, near Orange.
Lyndhurst, near.

Macleay River, Hickey's Creek.
Malongulli, Parish of, County of Bathurst.
Manar.
Manildra.
Marulan.
Marulan, ten miles from.
Melrose.
Melrose River, near Yellow Mountains.
Metagingie.
Middle Flat, Cooma.
Milburn Creek.
Milthorpe, eighteen miles from.
Mitchell's Creek.
Molong District.
Molong, fourteen miles west of.
Monaro District.
Moonan Brook.
Mootwingie, 100 miles north-east of Broken Hill.
Morton's Creek.
Mount Allen, near.
Mount Buffalo.
Mount Carrington, Drake.
Mount Costigan, Tuena.
Mount David, near Rockley.
Mount Drysdale.
Mount Gipps.
Mount Hope.
Mount McDonald.
Mount Stromboli, near.
Mount Werong.
Mountain Run, Rockley.
Mudgee.
Mulga Creek.
Mulloon Creek, near Braidwood.
Mumwell, ten miles from Goulburn.
Murrumbidgeree, Wellington District.
Muttama.
Myalla.

Nangeribone Run, Nymagee.
Narellan, Parish of, County of Monteagle.
Narrandera.
Narrangarie, near Talbragar.
Nelligen.
Nelson's Bay.
Newbridge.
Newbridge, near. (Colo Creek).

New England.
Nobbie's Hill.
Nobby Point, Port Macquarie.
Nulga, Parish of, County of Lincoln.
Nundle, and Bowling Alley Point, between.
Nymagee.

Oberon District.
Oberon, forty miles south of.
Oberon, Scrubby Paddock.
O'Connell, near.
Ophir.
Orange, near.
Orange Plains.

Palmer's Oakey.
Parkes, near.
Parkes, seven miles north of.
Parkes (Far Away Gully).
Peak Hill.
Peel district, near Bathurst.
Peelwood.
Perth, near Bathurst.
Piallamore, Parish of.
Plant Gully, near Emmaville.
Ponto.
Pulganbar, Parish of.
Purnamoota.

Quedong.
Queanbeyan, two miles north-east of.
,, three miles east of.

Razorback.
Reedy Creek, near Goulburn
Rockley.
,, eleven miles from.
Rockwell Paddock, near Broken Hill
Rosedale, near Orange
Rydal, near
Rye Park.
Rylstone, ten miles from.

Sawpit Gully, Drake
Scone (Watson's Reef).
Shoalhaven River.
Shooter's Hill.
Silverton.
Singleton.
Snowy River.
Spicer's Creek.
Spring Creek, eight miles from Bungonia.
Strathbogie.
Sturt Town.
Sugarloaf Hill, near Wellington.
Summer, Parish of, County of Bathurst.
Sunny Corner.
Swallow's Nest.
Swamp Oak.

Tacking Point, Port Macquarie.
Talbragar (Narrangarie).
Tamworth, sixteen miles from.
Tarago.
Taree, twenty miles from.
Temora.
Tenterfield, near.
Thackeringa.
Three-mile Flat, Wellington.
Tinda Tank.
Tingha.
Tomingley, Bogan River.
Tooloom.
Trangie, near.
Trunkey.
Tuena.
Tuena, three and a half miles south-east of.
Tuglow River.
Tumbarumba.
Tumut District.
Tumut and Adelong, between.

Ulladulla.
Upper Bingara.
Uralla.

Walcha.
Wallerawang.
Walli, near Cowra.
Wandsworth.
Warengo District.
Warneton.
Wattle Flat.
Waugoola.
Wee Jasper, twenty miles from Yass.
Wellbank, Wellington
Wellington, ten miles north of.
Werong.
Wertago, Wilcannia District.
Westville.
Whipstick.
Wilcannia.
Willie Willie, Macleay River.
Windellama.
Wiseman's Creek.
Woodstock, four miles south of.
Wough Gully, fourteen miles east of Tamworth.
Wyalong.
Wyangle, County of Buccleuch
Wyndham.

Yarrangobilly.
Yass.
Yellow Mountain.
Yeoval.
Yulgilbah.

*Production of Copper (ingots, ore, and regulus).*

TABLE showing the quantity and value of Copper exported from New South Wales, from 1858 to 1899.

| Year. | Ingots. | | Ore and Regulus. | | Total. | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | Quantity. | Value. | Quantity. | Value. |
| | tons. cwt. | £ | tons. cwt. | £ | tons. cwt. | £ |
| 1858 ... | ..... ...... | ....... .. | 58 0 | 1,400 | 58 0 | 1,400 |
| 1859 ... | 30 0 | 578 | ...... ..... | ......... | 30 0 | 578 |
| 1860 ... | ......... .. | ......... | 43 0 | 1,535 | 43 0 | 1,535 |
| 1861 ... | ... ........ | ......... | 144 0 | 3,390 | 144 0 | 3,390 |
| 1862 ... | ............ | ......... | 213 0 | 5,742 | 213 0 | 5,742 |
| 1863 ... | 23 0 | 1,680 | 114 0 | 420 | 137 0 | 2,100 |
| 1864 ... | 54 0 | 5,230 | ........... | ......... | 54 0 | 5,230 |
| 1865 ... | 247 0 | 15,820 | 22 0 | 545 | 269 0 | 16,365 |
| 1866 ... | 255 0 | 18,905 | 23 0 | 1,885 | 278 0 | 20,790 |
| 1867 ... | 393 0 | 30,189 | 0 2 | 5 | 393 2 | 30,194 |
| 1868 ... | 644 0 | 23,297 | 172 10 | 4,000 | 816 10 | 27,297 |
| 1869 ... | 1,980 0 | 74,605 | 104 0 | 2,070 | 2,084 0 | 76,675 |
| 1870 ... | 994 0 | 65,671 | 6 0 | 60 | 1,000 0 | 65,731 |
| 1871 ... | 1,350 0 | 87,579 | 94 0 | 1,297 | 1,444 0 | 88,876 |
| 1872 ... | 1,035 0 | 92,736 | 417 0 | 13,152 | 1,452 0 | 105,888 |
| 1873 ... | 2,795 0 | 237,412 | 51 0 | 1,690 | 2,846 0 | 239,102 |
| 1874 ... | 3,638 0 | 311,519 | 522 0 | 13,621 | 4,160 0 | 325,140 |
| 1875 ... | 3,520 0 | 297,334 | 157 0 | 4,356 | 3,677 0 | 301,690 |
| 1876 ... | 3,106 0 | 243,142 | 169 0 | 6,836 | 3,275 0 | 249,978 |
| 1877 ... | 4,153 0 | 307,181 | 360 0 | 17,045 | 4,513 0 | 324,226 |
| 1878 ... | 4,983 0 | 337,409 | 236 0 | 7,749 | 5,219 0 | 345,158 |
| 1879 ... | 4,106 15 | 256,437 | 36 7 | 915 | 4,143 2 | 257,352 |
| 1880 ... | 5,262 10 | 359,260 | 131 18½ | 4,799 | 5,394 8½ | 364,059 |
| 1881 .. | 5,361 0 | 350,087 | 132 16 | 4,975 | 5,493 16 | 355,062 |
| 1882 ... | 4,865 3 | 321,887 | 93 1 | 2,840 | 4,958 4 | 324,727 |
| 1883 ... | 8,872 17 | 574,497 | 84 10 | 2,704 | 8,957 7 | 577,201 |
| 1884 ... | 7,286 6 | 415,601 | 18 18 | 578 | 7,305 4 | 416,179 |
| 1885 ... | 5,745 5 | 264,905 | 0 15 | 15 | 5,746 0 | 264,920 |
| 1886 ... | 3,968 18 | 166,429 | 57 18 | 1,236 | 4,026 16 | 167,665 |
| 1887 ... | 4,463 19 | 195,752 | 299 8 | 3,350 | 4,763 7 | 199,102 |
| 1888 ... | 3,786 1 | 272,110 | 113 6 | 2,924 | 3,899 7 | 275,034 |
| 1889 ... | 3,983 16 | 203,319 | 198 4 | 3,322 | 4,182 0 | 206,641 |
| 1890 ... | 3,165 9 | 163,537 | 580 9 | 9,774 | 3,745 18 | 173,311 |
| 1891 ... | 3,860 3 | 191,878 | 665 8 | 13,215 | 4,525 11 | 205,093 |
| 1892 ... | 3,535 0 | 160,473 | 1,299 4 | 27,233 | 4,834 4 | 187,706 |
| 1893 ... | 1,051 0 | 44,235 | 1,016 0 | 14,191 | 2,067 0 | 58,426 |
| 1894 ... | 1,556 11 | 61,034 | 580 6 | 12,447 | 2,136 17 | 73,481 |
| 1895 ... | 2,793 3 | 119,300 | 1,058 0 | 21,585 | 3,851 3 | 140,885 |
| 1896 ... | 4,453 0 | 200,236 | 14 17 | 75 | 4,467 17 | 200,311 |
| 1897 ... | 6,756 3 | 299,829 | 166 5 | 851 | 6,922 8 | 300,680 |
| 1898 ... | 5,653 19 | 280,048 | 178 9 | 839 | 5,832 8 | 280,887 |
| 1899 ... | 4,640 15 | 330,120 | 1,337 3 | 69,694 | 5,977 18 | 399,814 |
| Totals | 124,367 13 | 7,381,261 | 10,968 14½ | 284,360 | 135,336 7½ | 7,665,621 |

Includes copper refined in New South Wales from imported ores, up to the end of 1898.

# ZINC.

The ores of zinc which occur in New South Wales, are as follow:—*Zincite*, *spartalite*, or *red oxide of zinc*, ZnO; contains 80·3 per cent. of zinc; crystallises in the hexagonal system; colour deep red, also orange-yellow; streak orange-yellow; translucent to sub-translucent; fracture sub-conchoidal; brittle. According to Professor Liversidge,* this mineral occurs in the Vegetable Creek District, where reddish-brown fragments of it have sometimes been mistaken for tinstone by the miners.

*Smithsonite, carbonate of zinc*, $Zn\,CO_3$; contains 52 per cent. of zinc; crystallises in rhombohedral forms; colour white, grayish, greenish, or brownish white, also green, blue, and brown; streak white; lustre vitreous to pearly; sub-transparent to transparent; occurs at Bredbo, Cooma District; was also very plentiful in the oxidised portion of the Broken Hill Silver Lode.

*Zincblende*, *sphalerite* or *black jack*. Composition sulphide of zinc, ZnS; contains 67 per cent. of zinc when pure; also often contains iron and manganese, and sometimes cadmium, and traces of some of the rare metals such as indium, gallium, etc. Crystallises in the Isometric system in tetrahedral forms; commonly massive, granular, and compact; also foliated, fibrous and radiated; colour yellow, brown, black, red-green, and white; streak brownish to light yellow, and white; transparent to translucent; lustre resinous to adamantine. Is the most common ore of zinc, and is found, associated with galena, in most of the silver-mines of New South Wales.

Although zincblende is one of the most widely distributed minerals in the Colony, no attempt has been made to mine it specially for the production of metallic zinc; on the contrary its occurrence is usually regarded as detrimental to the ores of silver and lead with which it is nearly always associated.

In the enormous deposits of sulphide ores which occur at Broken Hill, zincblende is one of the principal constituents. As already stated (in the article on silver) the Broken Hill sulphide ores consist of a crystalline granular mixture of galena and zincblende, with rhodonite and garnet, the two first named minerals being so intimately associated that it is frequently impossible to distinguish one from the other by the naked eye. Nevertheless, when the ore has been finely ground, it is possible to separate the galena from the blend by vanners, and it is then found that each of the minerals carries a proportion of the silver. For

* Minerals of New South Wales.

some years after the opening of the Broken Hill Mines the whole of the zinc contents of the ore was lost in the smelting operations, but subsequently a process of concentration was adopted, and this resulted in the saving of a proportion of zinc-concentrates,—particulars of which are appended. These zinc concentrates contain, on an average, twenty-one per cent. of zinc, eight and a half per cent. of lead, and eight ounces of silver per ton; but they also contain large proportions of the minerals rhodonite, and garnet, with some quartz. The presence of the two former prevents the further concentration of the product by ordinary mechanical appliances, owing to the small margin of difference between their specific gravities and that of zincblende. There are good reasons, however, for believing that this difficulty is about to be overcome by the use of the Wetherill Magnetic Separator,* and that by its means the zinc concentrates will be so enriched that the economic extraction of the metal from them will be possible. Should this process be successful, its value to the Broken Hill mines would be inestimable, for the price of zinc exceeds that of lead, and the latter is, at present, the principal source of revenue in the mines. The Broken Hill Lode is capable of producing enormous supplies of zinc for many years to come.

### *Distribution of Zinc Ores.*

THE following is a list of the localities from which specimens of zinc ore have been received in the Department of Mines for assay:—

Aconite, Parish of, County of Hardinge.
Albury.
Armidale District.
,, (Puddledock).
Ashford District.
Back Creek, Rockley.
Bega District.
Bingara.
Black Range, Albury.
Bolivia.
Boonoo Boonoo.
Boorook.
Borah Creek, near Inverell.
Boro, near Tarago.
Bredbo, Cooma District.
Broken Hill.
Bungonia (Spring Creek).
Burraga.
Burrowa, twenty-four miles west of.
Cangi, near Grafton.
Captain's Flat.
Clarevaulx, near Glen Innes.
Coolamon Plains, Kiandra.
Cooma, near.
Crookwell.
Cudgegong, near.
Deep Creek.
Deepwater River.
,, , thirteen miles from.
Denison Town.
Drake.
Elsmore (Newstead Mine).
Emmaville, near.
Fairfield, Drake.
Flyer's Creek, Carcoar District.
Glen Innes District.
,, , ten miles east of.
Goulburn, twelve miles from.
Grafton District.
Grampians, The, New England.
Inverell District.
,, eighteen miles from.
Jarrow Creek.
Jingellic.
Jinglemoney, near Braidwood.
Lewis Ponds, near Orange.
Little Plant Creek, near Emmaville.
Macleay River.
Marulan.
Meadow Flat.
Melrose.
Mitchell's Creek, Bathurst District.
Mole Station and Glen Creek, between.
Molong.

* Vide article on silver (Broken Hill Lode).

Moonabah, Macleay River.
Moruya.
Mount Buller, Queanbeyan.
Mount Costigan, near Tuena.
Mount Werong.
Mudgee District.
Nambucca.
Newbridge.
Nine-mile, near Deepwater.
Native Dog Creek, fifteen miles from Rockley.
Nundle.
Orange, near.
,, , thirty miles north of.
Parkes.
Pudman's Creek, Rye Park.
Purnamoota.
Pye's Creek, Bolivia.
Queanbeyan, near.
Red Rock, Drake.
Reedy Creek, New England.
Rockley (Native Dog Creek).
,, (Black Creek).
Severn River.
Shoalhaven River.
Singleton, near.
Solferino.
South Gundagai.
Spring Creek, Bungonia.
Sunny Corner.
Swanbrook.
Tait's Gully, near Armidale.
Tarana.
Tarrabandra, near Gundagai.
Tenterfield District.
Teralga (Mount Werong).
Tilbuster Creek.
Tingha, ten miles south-west of.
Tuena.
Warrell Creek.
Webb's Silver Mine, near Emmaville.
Webb's Consols Mine, south of Emmaville.
Wee Jasper.
Westmoreland, County of.
White Rock, Drake.
Yalwal, two miles from.
Yarrahapinni.

*Production of Zinc Concentrates.*

| Year. | Quantity. | Value. |
|---|---|---|
| | Tons. | £ |
| 1889 ... ... ... ... | 96·85 | 988 |
| 1890 ... ... ... ... | 210·45 | 2,378 |
| 1891 ... ... ... ... | 218·60 | 2,622 |
| 1892 ... ... ... ... | 444·55 | 5,055 |
| 1893 ... ... ... ... | ............... | ............... |
| 1894 ... ... ... ... | ............... | ............... |
| 1895 ... ... ... ... | ............... | ............... |
| 1896 ... ... ... ... | ............... | ............... |
| 1897 ... ... ... ... | 28,841·80 | 23,688 |
| 1898 ... ... ... ... | 38,941·30 | 28,941 |
| 1899 ... ... ... ... | 49,878·90 | 49,207 |
| Totals ... ... | 118,632·45 | 112,879 |

# LEAD.

LEADMINING was commenced at an early date in the history of the Colony, as shown by the following extract from a despatch, dated 1st March, 1849, from Governor Sir Charles Fitzroy to Earl Grey :—"A lead-mine was opened last year in the neighbourhood of Yass, but has been abandoned in consequence of its not being sufficiently productive to defray the expenses of working it.*

Native lead is of extremely rare occurrence by reason of the readiness with which the metal is oxidised. The Rev. W. B. Clarke, in several of his earlier reports, records the occurrence of small pieces of native lead in different localities. However, it is necessary to regard such specimens with great caution, as many samples of supposed native lead have been recived from time to time, the source of which could be clearly traced to rifle bullets or other artificial products.

The principal ores of lead are galena and cerussite.

*Galena*, or sulphide of lead—$PbS$; contains 86·6 of lead; specific gravity, 7·4—7·6; lustre metallic; colour and streak pure lead gray; is the most common ore of lead, and is found in small quantities (in lodes) in nearly all districts of the Colony. Always contains more or less silver.

*Cerussite*, or carbonate of lead—$PbCO_3$; contains 77·5 per cent. of lead; specific gravity, 6·46—6·57; lustre, adamantine to resinous; colour, white, gray, grayish-black; is the commonest variety of lead ore found in the upper or oxidised portions of lead-bearing lodes, and gives place to galena when the water level is reached. Carbonate of lead ores are also almost invariably found to be more or less argentiferous in this Colony.

Other ores of lead of less common occurrence are:—

*Minium*, or oxide of lead—$Pb_3O_4$; containing 90·66 per cent. of lead; specific gravity, 4·6; colour, red, mixed with yellow; occurs at Peelwood, Gundagai, Captain's Flat, and Mount Trooper, Snowy River.

*Anglesite*, or sulphate of lead—$PbSO_4$; contains 68·3 per cent. of lead; specific gravity, 6·3; lustre, adamantine, to resinous; colour, white tinged with yellow, gray, or green; found at Silverton, Wiseman's Creek, Campbell's Reef, Severn River, and other localities.

*Pyromorphite*, or phosphate of lead—$(PbCl) Pb_4P_3O_{12}$; contains 76·3 per cent. of lead; specific gravity, 6·5—7·1; lustre, resinous; colour, green, yellow, and brown; found at Broken Hill, Sugarloaf Hill, near Wellington, Mitchell's Creek, and at Silverdale, near Bowning.

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* *Votes and Proceedings Legislative Council*, 1851, Vol. II, p. 241.

*Mimetite*, or arseniate of lead—(PbCl) $Pb_4As_3O_{12}$ ; contains 69·5 per cent. of lead ; specific gravity, 7·0—7·25 ; lustre, resinous ; pale yellow to orange yellow and brown ; found at Sugarloaf Hill, Wellington ; at Mitchell's Creek, at Gulgong, and at Broken Hill.

*Wulfenite*, or molybdate of lead—$PbMoO_4$ ; contains 56·3 per cent. of lead ; specific gravity, 6·7—7·0 ; lustre, resinous or adamantine ; colour, wax-yellow to orange-yellow and bright red ; found at Molonglo, at Minmurra, and at Broken Hill.

*Stolzite*, or tungstate of lead—$PbWO_4$ ; contains 45·5 per cent. of lead ; lustre, resinous ; colour, green, yellowish-gray, brown, and red ; found at Broken Hill, and near Peelwood.

Lead-mining, *per se*, has not been practised to any extent in New South Wales. The reason for this is that all the lead ores hitherto discovered contain silver in greater or less proportion, and it was only natural that those which were richest in silver should be the first to be worked, as the market price of lead has not been sufficiently high in the past to allow of the remunerative working of those deposits which contained only a small proportion of silver, and which, by reason of their distance from the coast, were handicapped by the expense of freight to market. In nearly every case, therefore, the silver has been the principal metal sought for, and the lead has been regarded as a useful accessory, both for simplifying smelting operations and for recovery as a by-product.

The principal source of the lead hitherto produced in the Colony is the Broken Hill Silver Lode, where the ores have consisted chiefly of argentiferous cerussite in the upper or oxidised zone, and of argentiferous sulphides of lead and zinc in the lower or unoxidised portions. These sulphide ores are remarkably characteristic, and consist of an intimate crystalline mixture of galena and zincblende. The two minerals are so intimately mixed, that it is frequently impossible to distinguish one from the other by the naked eye, though a clean separation can be effected by crushing the material and treating it on vanners. When the separation has been made, it is found that the two minerals carry about equal proportions of silver.

When the Broken Hill Mines were first opened, and for some years subsequently, the ores were remarkably rich in silver, which formed the principal source of profit ; of late years, however, the ore from the lower workings has been found to contain a much lower proportion of silver, the price of which, moreover, has suffered a very considerable reduction. On the other hand, there has been an increasing production of lead, together with an improvement in the value of that metal, which has gone far towards compensating for the loss of revenue from silver.

The discovery of a cheap and efficient process for recovering the zinc contents of the Broken Hill ore is a problem which has been receiving much attention from those interested in the mines. The zinc, which has hitherto been sacrificed in the metallurgical treatment of the ore, is of even greater value than the lead; and in view of the fact that the deposits are of distinctly lower grade at greater depths, the future of the mines may be said to depend upon the adoption of a process that will enable the zinc to be recovered in a marketable form, and thus convert into an asset what is at present regarded as an objectionable ingredient of the ore. Great hopes were entertained, about two years ago, that the Ashcroft process would solve the difficulty; but after the erection of very extensive works at Cockle Creek, near Newcastle, it was found that the expense of treatment by this method was too great to leave a margin of profit on ores of the low grade now being extracted.

Annual Yield of Lead from the Broken Hill Proprietary Silver-mine, from 1886 to 1899 inclusive.

| Year. | Ore treated. | Lead produced. |
|---|---|---|
| | Tons. | Tons. |
| 1886 ... ... ... ... | 11,500 | 1,991 |
| 1887 ... ... ... ... | 47,211 | 9,348 |
| 1888 ... ... ... ... | 94,125 | 16,659 |
| 1889 .. ... ... ... | 157,184 | 25,076 |
| 1890 ... ... ... ... | 207,311 | 30,339 |
| 1891 ... ... ... ... | 286,118 | 41,688 |
| 1892 ... ... ... ... | 254,825 | 36,497 |
| 1893 ... ... ... ... | 490,510 | 47,343 |
| 1894 ... ... ... ... | 595,194 | 49,595 |
| 1895 ... ... ... ... | 522,882 | 33,071 |
| 1896 ... ... ... ... | 426,325 | 22,023 |
| 1897 ... ... ... ... | 387,814 | 23,347 |
| 1898 ... ... ... ... | 419,165 | 30,993 |
| 1899 ... ... ... ... | 267,716 | 35,654 |
| Total ... ... | 4,167,880 | 403,624 |

The Broken Hill Proprietary Silver-mining Company is the greatest producer of lead, but considerable quantities have also been produced by the neighbouring mines, such as "Block 10," "Block 14," the "British," the "Central," the "Broken Hill North," the "Junction," and the "Junction North." Moreover, in all these mines there are large reserves of ore. Lead ores, such as galena and cerussite, are of such common occurrence, disseminated through veins in various parts of the Colony, that it would hardly be worth while to attempt a description of all the deposits in which they have been recognised, more especially as, in a majority of instances, they are not present in sufficient quantity to be considered of commercial importance. Reference will only be made, therefore, to those lodes in which the lead ores are not sufficiently rich in silver to warrant their being regarded as payable argentiferous deposits, and a list will be appended of the localities where lead ores have been found.

*Belconon*, near Queanbeyan. A metalliferous lode occurs at Belconon, on the right bank of the Murrumbidgee River, and about 200 yards below the point where this river junctions with the Molonglo. In 1893, Mr. Geological Surveyor J. B. Jaquet reported upon this deposit in the following terms :—

"The country is composed of Silurian (?) slates, possessing for the most part an almost vertical dip, interstratified with beds of crystalline limestone, these sedimentary formations being intruded by large bosses and by dykes of quartz felsite. It is on the side of a hill, which overlooks the Murrumbidgee River, composed of quartz felsite, in which the Belconon ore deposit occurs.

"The lode trends N. 20° E., and, as far as one is able to judge from the work already performed, dips about 80°, at S. 30° E. A good western wall—which can be readily recognised by reason of the slickenside faces, and deposits of flucan upon it—has been discovered in one place, but no defined eastern wall would seem to exist. At present, however, in no place has a complete section of the lode been exposed in the workings. Immediately adjoining the western wall the deposit would seem to be composed entirely of quartz, galena, and other commonly occurring veinstones, but these give place beyond to country rock (quartz felsite), in which thin veins and small nests of ore occur.

"The plane of faulting which forms the western wall has evidently determined the position of the ore deposit, and in considering the probable extension of the latter, both in a vertical and horizontal direction, this slide may be placed as a favourable indication of its permanency. The lode has been opened from the hillside, on its western wall, by means of an open cutting, thirty-five yards long, which has penetrated into the rock for distances varying from four feet to ten feet; the face is still in ore.

"The ore at present won consists of galena, copper pyrites, and iron pyrites, associated in part with a gangue of quartz, and in part with quartz felsite. Very little oxidation appears to have taken place, and the only evidence in the workings situated on the outcrop which suggests that the ore has been affected by its proximity to the atmosphere, is the presence of a small quantity of copper carbonate.

"I selected four samples of the best ore from various places where the lode was exposed, and these samples were, on my return to town, assayed by Mr. J. C. H. Mingaye, F.C.S. They yielded as follows :—

| | | |
|---|---|---|
| (A) | Lead ... .. ... ... | 27·71 per cent. |
| | Gold ... ... ... ... | traces. |
| | Silver ... ... ... ... | 1 oz. 19 dwt. 4 gr. per ton. |
| (B) | Lead ... ... ... ... | 37·71 per cent. |
| | Gold ... ... ... ... | traces. |
| | Silver ... ... ... ... | 1 oz. 19 dwt. 4 gr. per ton. |

| | | | |
|---|---|---|---|
| (C) | Lead ... | ... ... ... | 10·65 per cent. |
| | Gold ... | ... ... ... | traces. |
| | Silver ... | ... ... ... | 1 oz. 8 dwt. 6 gr. per ton. |
| (D) | Lead ... | ... ... ... | 15·33 per cent. |
| | Gold ... | ... ... .. | traces. |
| | Silver ... | ... ... ... | 1 oz. 8 dwt. 6 gr. per ton. |

"Having regard to the result of these assays, I am unable to speak favourably of the Belconon lode. . . . . The average quantity of lead contained in these picked samples is only 22·8 per cent., and taking lead as worth £13 per ton, the utmost value of the prospects of the ore after treatment would be £2 17s. Now it will, I think, at once be apparent that this sum of money would not be sufficient to pay for the cost of mining, dressing, and smelting, at a spot distant twenty miles from the railway. The silver and gold, it need hardly be said, are not present in sufficient quantities to pay for their own extraction. I was shown, elsewhere, on Mr. Campbell's run, a spot where shode stones of galena had been obtained, and the district for some distance around, would appear to be likely to contain metalliferous deposits."

*Cullulla.*—Deposits of lead ore were discovered about ten years ago in the Parish of Cullulla, County of Argyle, about eleven miles to the east of Tarago Railway Station. Four shafts (the deepest of which was about seventy feet) were put down on a lode which dipped W. 20° S., at an inclination of 20° with the horizon. This lode was found to contain rounded masses, or slugs, of carbonate of lead, and similar masses were also scattered through the shales and mudstones forming the country rock, close to the outcrop of the lode. This ore was probably the result of the oxidation of a galena lode, but no solid deposit of the latter mineral was discovered (possibly because sufficient prospecting was not done), and the workings were abandoned.

In 1893 a galena lode was discovered about five chains to the south of the old workings. It dipped in a direction of E. 30° S., at an angle of about 70°. The lode was very narrow at the surface, but widened out to six feet at a depth of ninety-six feet. It consisted of a dark, shaly gangue, with streaks and bunches of fine grained galena, and with occasional patches of black carbonaceous shale. The width of the deposit proved to be variable; a representative sample, taken right across the lode, where its width was 3 feet 6 inches, yielded by assay 15·45 per cent. of lead, and 2 oz. 9 dwt. of silver per ton. In 1896 the workings had attained a depth of 264 feet.

## *Distribution of Lead Ores.*

The following is a list of the localities from which specimens of lead ores have been forwarded to the Department of Mines for assay:—

Abercrombie Ranges.
Albury, near.
Argyle, County of.
Armidale (Tait's Gully).
Back Creek, Rockley.
Balderogery.
Barrier Ranges.
Bathurst, near.
Bega District.
Belara.

Bellinger River.
Bemboka.
Berthong.
Binalong.
Binda District.
Bobadah.
Boggy Camp, near Inverell.
Bolivia.
,, , thirty miles west of.
Bombala.
Boorook.
Borah Creek, near Inverell.
Boro, near Tarago.
Braidwood, near.
Bredbo.
Brewarrina.
Brewongle.
Brindabella, twelve miles from.
Broken Hill.
Brooke's Creek, near Gundaroo.
Broula.
Bull Dog Range, Mitchell's Creek, Bathurst district.
Buddawang.
Bundarra.
Bungonia.
Burra Burra, thirty miles north-east of.
Burraga.
Burragorang.
Burrowa.
Camden District.
Canbarra.
Candelo.
Captain's Flat.
Carcoar.
Castlerag, near Deepwater.
Clyde River, thirty miles from Braidwood.
Cobar.
Colinton.
Condobolin.
Cookbundoon.
Coolamon, Parish of, County of Cowley.
Coolaman Plains, Kiandra.
Cooma, five miles from.
Cope's Creek.
Cowley, County of.
Cowra.
Cox's River.
,, , twelve miles from Hartley.
Crudine.
Cullen's Creek.
Cullulla.
Cumnock.
Curragh Creek, Windellama.
Deepwater District (Castlerag).
,, ten miles from.
Denison Town.
Dilga River.
Dixon's Swamp, Woomargama.
Drake (Red Rock).
,, (White Rock).
Duckmaloi.
Elsmore (Newstead Mine).
Emmaville, near.
Eugowra.
Everton Mine, near Yass.
Fairfield, Drake.
Gininderra.
Glenburn.
Glen Innes, near.
Gordon, Glen Innes District.
Gordon's Reef, near Strathbogie.
Goulburn District.
Gowonglah.
Gulgong, six miles from.
Gundagai, near.
Gundaroo, near.
Humewood, near Yass.
Inverell.
Jenolan Caves, near.
Jinglemoney, near Braidwood.
Kiandra, near.
Lachlan River, thirty miles below Forbes.
Lake George.
Lawson.
Leadville.
Lewis Ponds, near Orange.
Little Hartley.
Locksley.
Macleay River.
Marulan.
Matong Station, near Cooma.
Mayo, Parish of, County of Hardinge.
Melrose, near.
Menindie, Topaz Station, thirty-seven miles from.
Merimbula.
Meryula Station, near Nyngan.
Michelago, near.
Mitchell's Creek, Bathurst District.
Molong.
Molonglo.
Money Ranges, between Yass and Gundagai.
Moruya.
Mount Costigan, near Tuena.
Mount Galena, near Emmaville.
Mount Gipps.
Mount Grosvenor, near Peel.
Mount McDonald.
Mount Sperraby, Bolivia.
Mount Stewart (Leadville).
Mudgee District.
Mulloon.

Mundi Mundi Ranges, Silverton.
Murrumbidgee and Molonglo Rivers, near junction of.
Murrurundi.
Nambucca.
Nerriga District.
Newbridge.
Nimitybelle.
Nowra Ranges.
Nundle.
Nuntherungie.
Nyngan, near.
Oberon, near.
Obley.
O'Connell District.
Orange.
Peelwood.
Picton, near.
Pine Ridge, near Inverell.
,, , ,, Talbragar.
Pinnacles, Barrier Ranges.
Pudman Creek, near Rye Park.
Purnamoota, near.
Pye's Creek, Bolivia.
Queanbeyan.
,, two miles south of.
Quedong.
Reedy Creek, New England.
Restdown, Nyngan.
Rivertree.
Rockley.
Rockwell Paddock, near Broken Hill.
Rocky Hall.
Rye Park.
Rye Park, five miles from.
Severn River.
Silverton.
Snowy River.
Spring Creek, Bungonia.
Sunny Corner.
Talbragar.
Tarago.
Tarana, near.
Tavistock.
Tenterfield District.
,, , five miles south of.
Thackeringa.
Thirlmere district.
Tilbuster Creek.
Tingha, near.
,, ten miles south-west of.
Trunkey.
Tuena.
Tumut, five miles east of.
Walker's Hill, near Nymagee.
Walla Walla, near Rye Park.
Waverley, New England.
Weddin Mountains.
Wertago, Wilcannia District.
Wiseman's Creek.
Woolgarloo, near Yass.
Wyagdon.
Yalgogrin (Piccaninny Claim).
Yalwal, near.
Yancowinna, County of.
Yarrangobilly.
Yass.
Young, near.

*Production of Lead (Pig).*

| Year. | Quantity. | Value. |
|---|---|---|
| | Tons. | £ |
| 1889 ... ... ... | 522·30 | 6,711 |
| 1890 ... ... ... | 126·00 | 1,587 |
| 1891 ... ... ... | 190·65 | 2,025 |
| 1892 ... ... ... | 70·90 | 726 |
| 1893 ... ... ... | 425·80 | 4,205 |
| 1894 ... ... ... | 31·15 | 260 |
| 1895 ... ... ... | 19·80 | 197 |
| 1896 ... .. ... | 23·85 | 259 |
| 1897 ... ... ... | 31·85 | 398 |
| 1898 ... ... .. | 1,718·00 | 19,282 |
| 1899* ... ... | 4,819·10 | 99,789 |
| Totals ... ... | 7,979·40 | 135,439 |

* Includes lead-carbonates, 1,331·10 tons, valued at £43,774; and lead-chloride, 220 tons, valued at £11,834.

# IRON.

SEVERAL attempts have been made, at different times, to smelt the iron ores of New South Wales; but although a quantity of pig-iron of excellent quality has been produced, the cost of its production has hitherto been too great to allow of the establishment of the industry on a profitable basis. The principal causes of the failure of the experiment appear to have been the cost of carriage of coal and limestone, the high price of labour here as compared with the Old World, and the fact of Sydney being a free port. Thus we find that the pig-iron smelted at Mittagong in June 1865, cost the producers no less than £5 17s. 6d. per ton, at which figure it could not compete with the imported article. At the present time, however, coal and limestone could be obtained at much lower rates than were possible when the smelting furnaces were last in operation, and, with the near advent of the federation of the Australian Colonies, accompanied, as it doubtless will be, by a protective tariff against the outer world, it seems reasonable to expect that New South Wales will soon be in a position to produce sufficient pig-iron to satisfy the requirements of Australia. Even leaving this Colony's resources in iron ores out of consideration, there seems to be no reason why the excellent iron ores of Tasmania and New Caledonia should not be profitably smelted on our coast with the coke made from New South Wales Coal.

Iron smelting furnaces have been in operation at two localities in the colony, viz., at Mittagong, on the Great Southern Railway, between Sydney and Goulburn, and at Esk Bank, near Lithgow, on the Great Western Railway. A brief allusion to the history of these works may be of interest:—

*The Fitzroy Ironworks, Mittagong.*—In the neighbourhood of Mittagong there are several deposits of limonite (hydrous peroxide of iron) which owe their origin to chalybeate springs rising to the surface through the Hawkesbury Sandstones. These deposits are not, as a rule, of any great extent, and are usually found capping small hills. The land on which the purest limonite occurs was first taken up in the year 1848, by Messrs. Neale, Holmes, and Burton, who proceeded to erect a small blast furnace, and two beam engines; the larger engine drove a fan for the blast furnace, while the smaller one was used in connection with the cupola for a foundry. The Governor, Sir Charles Fitzroy, visited Mittagong on the occasion of the opening of the works, which he named the Fitzroy Iron Works. They were under the management of a Mr. Povey, who is said to have succeeded in making some pig-iron, but there appears to be no record of the quantity actually produced by him, and eventually (in 1855 ?), work was stopped owing to the undertaking not being profitable. The fuel used by Mr. Povey was wood-charcoal and coke, the latter being brought from Sydney or Newcastle at considerable expense.

The works remained idle until about the year 1862, when they were leased by Mr. Lattin, who pulled down the old furnace and beam-engine, and commenced the erection of others. He, however, only partially carried out this work, and in August, 1864, he surrendered his lease and plant to the Fitzroy Iron Works Company, stating that he was unable to complete his contracts.

In October, 1864, Mr. Hampshire was appointed manager of the works, and the directors were Messrs. E. Vickery, John Frazer, A. Davy, Thomas Chalder, S. Zollner, and William Griffin. Hampshire completed the erection of the furnace, which he at first tried to work with a cold blast, but he subsequently converted the latter into a hot blast. He also completed the blowing engines, foundry, &c. The furnace was blown in on the 2nd May, 1865, and from that date to the 30th June, following, he produced at the rate of 60 tons of pig-iron per week, at a cost of £5 17s. 6d. per ton. For the first month's smelting the charges amounted to :—

| | |
|---|---|
| Coal, 397½ tons ... <br> Ore, 432 tons ... <br> Limestone, 160 tons | Product—211 tons scrap-iron, 4 girders, and some other small castings. |

Subsequently the furnace was in blast for thirty-six weeks for a total yield of 2,394 tons of pig-iron, or at the rate of 66½ tons per week. Hampshire used as fuel a mixture of coke and anthracite. During his management the Company supplied a number of iron cylinders for use in the construction of the bridge over the Murrumbidgee River at Gundagai. These cylinders were cast direct from the blast furnace, as were also a number of girders, which were used in supporting the upper storeys of Vickery's Buildings in Pitt-street, Sydney. The iron produced by Hampshire, however, resulted in a loss to the Fitzroy Iron Works Company, and on the 21st April, 1866, the Works were again shut down.

On the 18th December, 1867, Mr. Thomas Levick arrived from England under engagement with the company to manage their property. Shortly after his arrival (in January, 1868), the rolling mills were leased by Messrs. Hughes and Hughes, with the object of converting the pig-iron in stock into merchant iron. They made a considerable quantity of plates and bars, but with little or no profit, and in June of the same year their lease was cancelled. From June to October, 1868, the rolling mill was leased to Bladen and Company with a similar result.

Mr. Levick on his arrival made a thorough examination of the property and reported favourably on the prospects of the Company. He then devoted a considerable amount of time to searching for coal, the anthracite being unsuitable for smelting, as it contained from 20 to 28 per cent. of ash. He also overhauled and renovated the works, and had got the blast furnace ready for starting when his health failed him, and

*Photographed by E. F. Pittman.*

THE OLD FITZROY IRON SMELTING FURNACE MITTAGONG.

he was obliged to return to England. He resigned on the 28th June, 1869.

On the 29th November, 1869, it was decided, owing to financial difficulties, to wind up the Fitzroy Iron Works Company, and on the 10th January, 1870, the mine and works were sold at auction for the sum of £10,000, Mr. John Frazer being the purchaser.

In 1874 Mr. David Smith was sent out from England to examine the property, and his report having been favourable, a new company was formed under the imposing title of the "Fitzroy Bessemer-Steel and Hematite Iron and Coal Company." In 1875 Smith brought out a number of engineers and other skilled workmen; he completed the charging apparatus at the top of the furnace, which had previously been worked as an open-topped one, and he constructed an expensive tramway over the mountain to the anthracite colliery; but although he spent a considerable amount of money, he does not appear to have smelted any iron from the ore.

Towards the end of the year 1875 Mr. Smith was succeeded by Mr. David Lawson, who came out from Wales to assume the management of the works. He started smelting operations on the 5th February, 1876, and between that date and the 16th March, 1877, he succeeded in producing 3,273 tons of excellent pig-iron, fifty-two tons of which were converted into merchant bars. The bars were all disposed of in Sydney, while of the pig-iron some was used in the Colony and some was exported. The anthracite on the Company's ground being unsuitable for smelting, and Mr. Lawson's Directors having instructed him to obtain suitable coal at any price, with the object of proving whether the ore was capable of producing pig-iron of good quality, he obtained his fuel from Lithgow and Bulli. The splint coal from Lithgow was used raw; the Bulli coal was converted into coke, which was shipped to Pyrmont, and conveyed thence by train to Mittagong. It consequently cost 20s. 6d. per ton laid on the furnace bank. The limestone was brought from Marulan, twenty-six miles distant, by train, and cost 16s. per ton delivered at the works.

In consequence of the great cost of the fuel (£3 for every ton of pig), in addition to the cost of limestone and labour, the pig-iron could not be produced at less than £5 per ton. The loss on the iron smelted by Mr. Lawson being thus very considerable, the shareholders were unwilling to continue paying calls, and the furnace was blown out, and has been idle ever since. The furnace charges used by Mr. Lawson were as follow:—

| | |
|---|---|
| Coke ... ... ... | 4 cwt. |
| Ore ... ... ... | 7 ,, |
| Limestone ... ... | $1\frac{3}{4}$ ,, |

He used altogether—

| | | |
|---|---|---|
| 1,351 tons of Bulli coal ... | | |
| 10,811 ,, Lithgow coal ... | | Product, 3,273 tons 13 cwt. pig-iron. |
| 7,119 ,, ore ... ... | | |
| 2,288 ,, limestone ... | | |

The sum of £22,536 was expended under Mr. Lawson's management (including cost of improvements, &c.) between November, 1875, and March, 1877.

In June, 1877, Mr. E. G. Larkin and Messrs. Hunter and Henshaw leased the rolling mills, with the object of converting pig into merchant iron, but in the following January the two last-named left Mittagong, and Mr. Larkin, after completing a contract to supply rails for the Joadja tramway, and paying all liabilities, closed the works in March, 1878, having found the venture unprofitable.

In 1884 the estate was sold to a new company called the Mittagong Land Company, who still own the property.

The works then remained idle until March, 1886, when the rolling mills were again leased, on this occasion by Mr. W. Sandford, with the object of re-working rails for the Government, and making sheet-iron. Mr. Sandford remodelled the mill, but after repeated trials for five or six months, he found the work unprofitable, and finally gave it up.

This was the last attempt to manufacture iron on a large scale at the Fitzroy Works. Mr. Larkin was left in charge by the Company, and realising that the failure of the previous undertakings was largely due to the want of good and cheap fuel, he recommended his Directors to bore for coal. Accordingly, in 1887, the use of a diamond drill was obtained from the Government, and at a depth of 642 feet a seam of coal, 8 ft. 11 in. thick, was struck. The following is a section of the seam :

| Roof, splint coal. | Ft. | in. |
|---|---|---|
| Bituminous coal ... ... ... ... | 0 | 4 |
| Coaly shale ... ... ... ... | 0 | 1 |
| Bituminous coal ... ... ... ... | 3 | 4 |
| Dark band ... ... ... ... | 0 | 2 |
| Bituminous coal ... ... ... ... | 5 | 0 |
| | 8 | 11 |

A sample of the lower five feet of bituminous coal gave on analysis :

| | |
|---|---|
| Moisture ... ... ... ... ... | 1·35 |
| Volatile hydrocarbons ... ... ... | 25·79 |
| Fixed carbon ... ... ... ... | 60·06 |
| Ash... ... ... ... ... ... | 12·24 |
| Sulphur ... ... ... ... ... | 0·56 |
| | 100·00 |

Specific gravity, 1·347. Coke, 72·30 per cent.

In 1890, Mr. W. Brazenall experimented with the limonite ore of the Fitzroy Mine and Mittagong coal, in a small cupola furnace, and he succeeded in producing some excellent iron, both pig and castings made direct from the furnace. These products, together with samples of the ore, coal, and limestone, were shown at the Mining Exhibition at the Crystal Palace, London, and gained a first award.

*The Eskbank Ironworks, Lithgow.*—The blast furnace at these works was first charged on the 16th December, 1875. The following is a copy of a report made by Mr. John Mackenzie, F.G.S., Examiner of Coal-fields, in 1877 :—

"The Eskbank Ironworks, Lithgow, are erected on coal property belonging to Thomas Brown, Esq., at Lithgow Valley, adjoining the Great Western Railway, and are situated about ninety-five miles from Sydney, fifty miles from Bathurst, and ninety-seven miles from Orange. The blast furnace is 55 feet in height and 12 feet across the boshes, and is driven by a 70 horse-power horizontal engine, with hot air oven, and all other appliances necessary for a first-class blast furnace.

"Last December they were producing pig-iron at the rate of about 100 tons per week. The iron ores used are clay-band, from the property on which the works are erected, brown hematite from Back Creek, near Blayney, situated about seventy-seven miles west from the works by rail (the Great Western Railway running through the deposit); also, red siliceous hematite from the Company's property at Mount Wilson, alongside the Great Western Railway, and about twelve miles from the works, and brown hematite from the Clarence tunnel, adjacent to the Great Western Railway, and about seven miles from the works. Limestone is procured from Piper's Flat, a distance of fourteen miles from the works, and seven miles from the Wallerawang railway station. The coal used is the Eskbank Colliery splint coal, which burns to a white ash, and is procured from a 10 feet 6 inch seam adjacent to the blast furnace. The Company have also erected during the year a foundry for making their own castings for the rolling mills, furnaces, &c. The rolling mill consists of a 100 horse-power engine, 18-inch mill, six puddling furnaces, one ball furnace and two mill furnaces, a Nasmyth steam-hammer, and all the necessary appliances for converting pig into bar-iron on the premises; and they are now importing and making the plant necessary for the manufacture of galvanised iron. Enoch Hughes, Esq., is the Manager."

The production of pig-iron at these Works ceased in the year 1882, presumably because the industry proved unremunerative; since that time the works have been continuously employed in the manufacture of bars, rails, &c., from scrap-iron. The following table shows the output of the Eskbank Ironworks while the blast furnace was in operation for the reduction of iron-ore :—

| Year. | Pig iron produced. | Bars and rails produced. | Castings. | Bolts and nuts. | Value |
|---|---|---|---|---|---|
| | Tons. | Tons. | Tons. | Tons. | £ |
| 1875 | ......... | 40 | ......... | ......... | 502 |
| 1876 | 80 | 482 | ......... | ......... | 3,843 |
| 1877 | ......... | ......... | ......... | ......... | ......... |
| 1878 | 389 | 511 | ......... | ......... | 6,656 |
| 1879 | 118 | 1,000 | ......... | ......... | 10,550 |
| 1880 | 1,200 | 800 | ......... | ......... | 12,800 |
| 1881 | 2,737 | 3,351 | 220 | 51½ | 47,876 |
| 1882 | 4,320 | 2,139 | 1,017 | ......... | 37,224 |

The following are the principal ores of iron found in the colony:—

*Magnetite, magnetic iron ore;* sesquioxide and protoxide of iron; $FeO$, $Fe_2O_3$ contains 72·4 per cent. of metallic iron when pure. Frequently contains titanium, which, when present in quantity, renders it difficult to smelt. Occurs in octahedral crystals, also massive, and as loose sand. Lustre, metallic to sub-metallic; colour, iron-black; streak, black; strongly magnetic. Hardness, 5·5—6·5; specific gravity, 5·16—5·18. Magnetite contains a higher percentage of iron than any other ore. Occurs in the Parish of Falnash, near Wallerawang; at Cadia, near Orange; at Mount Lambie, near Tarana; at Mount Wingen, County of Brisbane; at Solferino, County of Drake; at Brown's Creek, County of Bathurst; at Ironstone Mountain; and on the Williams River, Port Stephens District, where it contains about 8 per cent. of titanic acid.

*Hematite; red hematite; specular iron.* Iron sesquioxide; $Fe_2O_3$; contains 70 per cent. of metallic iron when pure. Occurs in rhombohedral crystals; also massive or compact, fibrous, ochreous, and micaceous. Lustre, metallic to dull; colour, dark steel gray, or iron-black; when earthy, red; streak, cherry-red or reddish-brown; hardness, 5·5—6·5; Specific gravity, 4·9—5·3. Specular iron ore occurs at Cadia, near Orange; Summer's Hill, near Bathurst; at Mount Lambie, near Tarana; and at Mount Gobondery, near Fifield, &c. Micaceous hematite occurs at Dungowan Creek, County of Parry; at Bibbenluke, County of Wellesley, and at other localities.

*Limonite, Brown Hematite, Bog-iron-ore.*—Composition hydrous peroxide of iron, $2Fe_2O_3$, $3H_2O$; contains 59·8 per cent. of iron and 14·5 per cent. of water; not crystallised, usually in stalactitic or mammillary forms having a fibrous structure, also concretionary, massive, and sometimes earthy; hardness, 5–5·5; specific gravity, 3·6–4; lustre silky, often sub-metallic, sometimes dull and earthy; colour of freshly-fractured surface, various shades of brown; exterior surface sometimes nearly black, and appears as if varnished; the earthy varieties are brownish-yellow; streak, yellowish-brown; opaque. The variety known as bog-iron-ore is generally loose or porous in texture, and often contains organic remains such as pieces of wood, leaves, fossil nuts, &c.

Occurs in the neighbourhood of Mittagong, Picton, Piper's Flat, near Wallerawang, Jamberoo, Jervis Bay, &c.

*Ferruginous bauxite,* or hydrous alumina, containing a greater or less proportion of hydrous peroxide of iron, occurs a number of localities in the neighbourhood of Wingello, Inverell, Emmaville, &c. It is generally massive, and is frequently found in a pisolitic form. Further particulars of this ore are given in the article on aluminium.

*Chalybite, Spathic Iron Ore.*—Composition, carbonate of iron, $FeCO_3$; contains 48·3 per cent. of iron; crystallises in the hexagonal system in rhombohedral forms, also massive, globular, and botryoidal; lustre vitreous, more or less pearly; colour gray, yellowish-gray, brown, and brownish-red; streak white; translucent to sub-translucent; fracture uneven; brittle; hardness, 3·5—4·5; specific gravity, 3·7—3·9. Occurs in the Australian Broken Hill Consols Lode and, in small quantities, in a number of other metalliferous mines, but has never been found in deposits of sufficient size to be regarded as an ore of iron.

*Clay-band*, or *Clay-iron-ore*, is a mixture of carbonate of iron with a certain proportion of clay or earthy matter. A sample of clay-iron-ore from Genowlan, Parish of Airly, County of Roxburgh, was analysed in in the Department of Mines, and had the following composition:—

| | | |
|---|---|---|
| Moisture at 100° C. ... ... ... | ·700 | |
| Combined water ... ... ... ... | 2·650 | |
| Ferrous carbonate ($FeCO_3$) ... ... | 54·713 | = 26·41 metallic iron. |
| Silica ($SiO_2$) ... ... ... ... | 11·930 | |
| Alumina ($Al_2O_3$) ... ... ... ... | 4·639 | |
| Calcium carbonate ($CaCO_3$) ... ... | 14·553 | |
| Potash ($K_2O$), Soda ($Na_2O$) ... ... ... ... | ·242 | |
| Phosphoric anhydride ($P_2O_5$) ... ... | ·189 | |
| Manganous oxide (MnO) ... ... | minute trace. | |
| Magnesium carbonate ($MgCO_3$) ... | 8·133 | |
| Strontium carbonate ($SrCO_3$) ... ... | trace. | |
| Copper oxide (CuO) ... ... ... | minute trace. | |
| Organic matter ... ... ... ... | 2·552 | |
| | 100·301 | |

Bands of what has been termed clay-iron-ore are of frequent occurrence in the Coal Measures; they are of variable thickness, but the maximum is seldom more than about six inches. They consist, at their outcrops, of earthy limonite, which is, probably, the result of the oxidation of clay ironstone. On account of their inconsiderable thickness they are not likely to form an important source of iron in New South Wales.

The principal deposits of iron ore in the Colony were described in 1891 by Mr. C. S. Wilkinson, F.G.S., the late Geological Surveyor-in-Charge. He reported that they are situated near Mittagong and Picton townships, on the Great Southern Railway line, and near the townships of Wallerawang and Rylstone, on the Great Western Railway; these localities were also alluded to as the most favourable for the establishment of smelting works, on account of the proximity of workable seams of coal, together with unlimited supplies of limestone. Scattered through the outlying districts, and more or less accessible to the railway lines, are numerous other deposits of iron ore, which would also be available for smelting works in the above-mentioned localities. Mr. Wilkinson estimated that the different ore deposits in the Mittagong Coal District contained, in sight, about 2,872,000 tons of brown hematite, which, according to analysis, contains an average of 48·4 per cent. of metallic iron. The quantity of iron ore, in sight, in the different deposits throughout the Goulburn and other districts, within from 45 to 100 miles by rail from Mittagong, was roughly estimated at 4,000,000 tons.

The Picton deposits, eight miles from the town of that name, consist of brown hematite, and are precisely similar in origin to those of Mittagong, having been formed at the surface by ferruginous springs; they could not, therefore, be expected to extend to a great depth below the surface. On the assumption that their average depth is about twenty-five feet, they were estimated to contain 1,362,060 tons within an area of about fourteen acres. A sample of the ore from the largest of these deposits was taken by Mr. Wilkinson, and analysed by Mr. J. C. H. Mingaye, with the following result:—

| | |
|---|---|
| Moisture at 100° C. ... ... ... ... | 1·77 |
| Combined water ... ... ... ... ... | 11·88 |
| Ferric oxide ... ... ... ... ... ... | 71·55* |
| Ferrous oxide ... ... ... ... ... | trace |
| Manganous oxide ... ... ... ... ... | trace |
| Alumina ... ... ... ... ... ... | 10·35 |
| Lime ... ... ... ... ... ... ... | nil. |
| Magnesia ... ... ... ... ... .. | ·25 |
| Silica ... ... ... ... ... ... ... | 4·10 |
| Sulphuric oxide ... ... ... ... ... | trace |
| Phosphoric oxide ... ... ... ... ... | trace |
| | 99·90 |

* Equal to 50·09 per cent. of metallic iron.

An average sample of soft argillaceous brown hematite from another deposit on the same property yielded—

40·35 per cent. of metallic iron.
23·00 ,, ,, silica.
26·35 ,, ,, gangue.

An average sample of mixed compact and soft argillaceous brown hematite was taken from another of these deposits, and was found to contain—

37·56 per cent. of metallic iron.
23·80 ,, ,, silica.
28·95 ,, ,, gangue.

It will be seen therefore that Mr. Wilkinson's estimate of the total quantity of iron ore, which would be available for smelting works situated in the Mittagong Coal-field and near the railway was 8,234,060 tons, including the brown hematite ore occurring in lodes and pockets in the Goulburn and adjacent districts outside the coal-field. As will be shown later on, however, more recent investigations have proved that this estimate is much too high.

The iron ore deposits in the districts traversed by the Great Western Railway line were also reported by Mr. Wilkinson to be much scattered, but he was of opinion that those accessible to the railway, taken collectively, contain sufficient ore to warrant the establishment of smelting works on the coal-fields, either near Wallerawang, or Rylstone, where there is abundance of limestone.

Unlike the deposits of Mittagong and Picton, the iron ores of the Western District occur in lodes and pockets, but they also consist of brown hematite, with magnetite in places, and also garnet rock and clayband ore. The latter occurs as irregular lenticular bands from a few inches up to eighteen inches thick in the Coal Measures, and though it was estimated that several thousand tons might be collected from the surface of the hills where the Coal Measures have been denuded, it was not considered probable that the bands could be profitably mined *in situ*, owing to their variable thickness.

The Wallerawang deposits had been but little exploited, and the quantity of ore in them could not be stated, but it was estimated that within a depth of fifty feet from the surface it would not exceed 400,000 tons, and this quantity, by itself, would not warrant the establishment of smelting works; however in the Blayney, Cowra, Carcoar, and Orange Districts, in places within moderate distance from the railway lines, occur deposits of hematite and magnetite, the principal of which were examined and described by Mr. Carne, who estimated that the three largest deposits contain about 1,080,000 tons of ore, yielding by analysis from 50·65 to 58·06 per cent. of metallic iron, with only a trace of phosphorus and no sulphur.

The remaining deposits scattered throughout the Wallerawang District do not probably contain, according to Mr. Wilkinson's estimate, more than one million tons of ore in sight, and therefore the total quantity of ore available for smelting works which might be started in this field was stated by him to be approximately 2,480,000 tons.

The deposits from which iron ore could be obtained for smelting works in the event of the industry being started where the coal and limestone occur near Rylstone, were reported on in 1891, by Mr. Geological Surveyor T. W. E. David, who found them to be developed chiefly at (1) Ilford, (2) Carwell Creek, near Rylstone, (3) Cox's selection, in the Parish of Dungaree, and (4) Lue, also in the Parish of Dungaree, County of Phillip. The first of these deposits was stated to be of some extent, but was not geologically examined. Deposits 2,, 3 and 4 were geologically examined, their contents estimated, and their average yield of metallic iron tested by analysis of a number of samples. Mr. David was of opinion that all these deposits represented the oxidised portions of pyritous veins, and stated that there could be little doubt that at a depth they will all pass from oxides into sulphides. They were found to be developed (*a*) along lines of disturbance, such as anticlinal axes, and (*b*) along contact lines between eruptive and sedimentary rocks. They are usually situated either in, or in close proximity to extensive beds of limestone, which are probably of Siluro-Devonian age.

In the Lue deposit, small kernels of pyrites were observed in places where the siliceous nature of the ore material had arrested the decomposition of the sulphides. In places also the siliceous portions of this deposit were found to be quite cellular from the decomposition and subsequent removal of cubical crystals of iron pyrites.

The Rylstone, Dungaree, and Lue deposits were described in each case as consisting of (*a*) an oxidised capping of brown hematite, passing into poorer ore, containing more or less of alumina and silica as impurities, and below this of (*b*) a mass of ferruginous felspathic material, traversed by numerous small and large veins of hydrated oxides of iron, and hematite, with, in some cases, a little manganese. The greatest depth to which any of these deposits had been tested was 100 feet. The nature of the iron-ore deposits at Lue, at the bottom of a 100-feet shaft, was carefully examined, and it was found to be still in the condition of brown or red oxide, with a good deal of felspathic material mixed with it. In view of this fact, a probable depth of 100 feet of brown iron ore in these deposits was assumed when estimating the quantity of ore contained in them, although it was considered likely that many of them will extend downwards in the same condition for 200 feet, or even more, before they pass into sulphides.

The following are the quantities of ore estimated by Mr. Geological Surveyor David to be available at the three localities, the specific gravity of the ore being taken at 3·25, and the weight per cubic yard at 2·44 tons:—

(2.) At Carwell Creek, near Rylstone, 70,000 tons of ore, in deposits already partially explored, which would contain on the average about 43 per cent. of metallic iron = 30,100 tons of metallic iron. These deposits are three miles distant in a westerly direction from the Mudgee railway line at Cumber Melon, where there is a good workable seam of coal suitable for smelting purposes; they are also either in or contiguous to extensive beds of limestone.

(3.) At Cox's selections, Portions 42 and 97, Parish of Dungaree, County of Phillip, the deposit as seen on the surface is evidently the cap of a large pyrites fissure vein, and there are here about 25,500 tons of ore from the surface to a depth of six feet, averaging 43 per cent. of metallic iron, and therefore containing about 11,000 tons of metallic iron. If the lode continue workable to a depth of 100 feet, assuming the yield below the cap to be one-half that of the cap itself, there will be available about 260,000 tons of ore, containing about 110,000 tons of metallic iron. The distance of these deposits from the nearest point of the Mudgee railway line is about five miles; they are also about five and a half miles from the Rawdon Colliery, where there is a good seam of workable coal. There is an extensive bed of good limestone about a quarter of a mile to the south-east of the southern extremity of the ironstone lode. The following analyses of average samples selected by Mr. David, were made by Mr. J. C. H. Mingaye, in the Laboratory of the Department of Mines :—

*Complete Analysis.*

Sample No. 110.

| | | |
|---|---|---|
| Moisture at 100° C. ... ... ... | ·25 | |
| Combined water, and organic matter | 8·97 | |
| Peroxide of iron ... ... ... | 66·79 | = 46·75 % metallic iron. |
| Protoxide of manganese ... ... | trace | |
| Silica ... ... ... ... ... | 14·41 | |
| Alumina... ... ... ... ... | 8·23 | |
| Lime ... ... ... ... ... | trace | |
| Magnesia ... ... ... ... | ,, | |
| Phosphoric anhydride ($P_2O_5$) ... | ·49 | |
| Sulphur trioxide ($SO_3$) ... ... | ·48 | |
| | 100·32 | |

*Partial Analyses.*

Sample No. 111.

| | | |
|---|---|---|
| Gangue ... ... | 25·60 | per cent. |
| Silica ... ... | 19·10 | ,, |
| Metallic iron ... | 43·19 | ,, |

Sample No. 112.

| | | |
|---|---|---|
| Gangue ... ... | 24·44 | per cent. |
| Silica ... ... | 19·16 | ,, |
| Metallic iron ... | 42·74 | ,, |

Sample No. 113.

| | | |
|---|---|---|
| Gangue ... ... | 25·94 | per cent. |
| Silica ... ... | 19·55 | ,, |
| Metallic iron ... | 41·18 | ,, |

Sample No. 114.

| | | |
|---|---|---|
| Gangue ... ... | 29·54 | per cent. |
| Silica ... ... | 23·25 | ,, |
| Metallic iron ... | 38·85 | ,, |

Sample No. 115.

| | | |
|---|---|---|
| Gangue ... ... | 5·01 | per cent. |
| Silica ... ... ... | 3·97 | ,, |
| Metallic iron... ... | 55·43 | ,, |

About one mile and a half to the south-east of the preceding are two contiguous ore deposits, with limestone on one side and slate on the other. Their total contents of iron ore, to a depth of 100 feet, was estimated at 44,000 tons, equal to about 19,000 tons of metallic iron.

(4) The Lue deposit was found to be more siliceous than any of the others. It had been sunk upon to a depth of 100 feet, and the estimated total contents of ore, to this depth, was 152,000 tons, equal to about 65,400 tons of metallic iron. It is situated about two miles from the nearest point of the Mudgee railway, and within half a mile of it occurs a small bed of limestone.

Two other outlying deposits were examined by Mr. David, at Cooyal and Denison Town respectively. The Cooyal deposit was estimated to contain, within 100 feet from the surface, about 300,000 tons of ore, and the Denison Town deposit (at Mount Stewart) about 400,000 tons.

Summary of quantity of iron ore estimated to occur in or near the district traversed by the Mudgee railway.

| | Ore. | | Metallic iron. |
|---|---|---|---|
| At Carwell Creek, near Rylstone ... ... | 70,000 tons | = | 30,100 tons. |
| At Cox's selections, parish of Dungaree ... | 260,000 ,, | = | 110,000 ,, |
| One and a half miles south-east of Dungaree... | 44,000 ,, | = | 19,000 ,, |
| At Lue ... ... ... ... ... ... | 152,000 ,, | = | 65,400 ,, |
| | 526,000 ,, | = | 224,500 tons. |

*Outlying deposits.*

| | |
|---|---|
| Cooyal ... ... ... ... ... ... | 300,000 tons. |
| Denison Town ... ... ... ... ... | 400,000 ,, |
| For other outlying deposits, such as those of Tallawang and Ilford, and continuations of the Cooyal deposits, perhaps as much as 1,000,000 tons might be added. | 1,000,000 ,, |
| Grand total ... ... ... ... | 2,226,000 ,, |

In his report on the iron ore deposits of New South Wales, published in 1891, Mr. C. S. Wilkinson summarised his conclusions as follows:—"It is thus evident that in New South Wales there are important deposits of rich iron ores, together with unlimited supplies of coal and limestone, suitable for smelting purposes; and that for the manufacture of steel of certain descriptions, abundance of manganese, chrome, and tungsten ores are available. There are three localities favourably situated for the establishment of smelting works, viz., near Mittagong or Picton, in the South-Western Coal-field, on the Great Southern Railway Line; near Wallerawang or Lithgow, on the edge of the Western Coal-field, on the Great Western Railway; and near Rylstone, also in the Western Coal-field, on the Wallerawang-Mudgee Railway."

"The ore in the latter localities might, if required, be worked together, and smelted at some central works near Wallerawang or other convenient site. The quantity of iron ore available for smelting works in the Mittagong or Picton District is estimated approximately at 8,234,000 tons, containing 3,684,000 tons of metallic iron; in the Wallerawang District, 2,484,000 tons of ore, containing 1,212,000 tons of metallic iron; and in the Rylstone District, 2,226,000 tons of ore, containing 957,180 tons of metallic iron; or a total quantity of 12,944,000 tons of ore, containing 5,853,180 tons of metallic iron."

"In reference to the Australasian imports of iron and iron manufactures, it may be of interest to quote the following remarks by Mr. T. A. Coghlan, Government Statistician:—'The average yearly import for the four years 1885–1888* amounts to £1,740,412 for New South Wales and £5,081,663 for Australasia, and the quantity of pig-iron required to produce the material represented by these values was approximately 153,000 tons and 460,000 tons per annum for New

* According to the Government Statistician's latest publication, the average yearly import of all descriptions of iron, machinery, and iron manufactures for the five years ending 1897 was £1,659,206 for New South Wales and £5,688,623 for Australasia.

*Photographed by E. F. Pittman.*

THE FITZROY IRON-ORE DEPOSIT, MITTAGONG.

South Wales and the whole group of colonies respectively.' Therefore at this rate the estimated quantity of iron capable of being produced in New South Wales would meet the demand of the colony for over 35 years."

At the time Mr. Wilkinson made his rather hurried examination of the iron-ore deposits it was a matter of great difficulty to arrive at even an approximate estimate of the quantities available, owing principally to the very limited amount of prospecting work performed upon them, and the consequent uncertainty as to the depth to which the workable ore extended. Recently it was decided to have all the principal iron-ore deposits carefully examined and mapped by a member of the Geological Survey Staff. The work was undertaken by Mr. J. B. Jaquet, and is still in progress, and with the object of assisting the investigation as much as possible, and supplying some practical evidence as to whether the deposits are really of sufficient importance to warrant the starting of the iron-smelting industry, the Government decided to expend a sum of money in putting down shafts and diamond-drill bores. These exploratory works have proved that in several instances the quantity of ore suitable for smelting purposes is much lower than was previously supposed. Thus the Fitzroy deposit at Mittagong, which had been estimated to have an average depth of 25 feet, was proved by boring to have a maximum depth of only 19 feet 6 inches, its average depth being considerably less. Almost equally disappointing results were obtained in the case of the other deposits along the Southern Railway Line, and Mr. Jaquet's investigations, so far as they have been conducted, point to the probability of there being less than one million tons of good ore in the neighbourhood of Mittagong, about an equal quantity near Picton, and possibly between one and two million tons in the vicinity of Goulburn.

In the Wallerawang and Rylstone Districts the estimated quantity of ore in the deposits previously examined has also been found to be much too high; but on the other hand, it has been shown by Mr. Jaquet that other deposits (within a reasonable distance of Lithgow), which had not been included in Mr. Wilkinson's estimate, although their existence had been known for many years, probably contain supplies of iron-ore far in excess of the total estimate of Mr. Wilkinson, and appear to leave no room for doubt as to there being sufficient material for the establishment of the iron-smelting industry in New South Wales.

*The Carcoar Deposits.*—Some of these deposits occur at Coombing Park, Portion 66, Parish of Somers, County of Bathurst, about two and a half miles in a southerly direction from the town of Carcoar. Attention was first directed to them by the late Mr. S. Stutchbury, Geological Surveyor, who in the year 1851 wrote as follows:—"In the great park at Coombing the summits of five small mountains, or hummocks (of from twenty to fifty or more acres each), are composed of a very rich compact hematite iron, much of it magnetic. . . . . The apparent quantity of iron is so immense, and if all things else were compatible with manufacture of iron, there is sufficient to supply another Sheffield for ages to come."

Mr. Jaquet reports that the country in the vicinity of the ore-bodies consists of Silurian slates, which are intruded by numerous narrow dykes or sills of andesite. He found thirteen distinct outcrops of ore, the dimensions of which are as follow :—

| Deposit. | Greatest length in feet. | Greatest width in feet. | Area in acres. |
|---|---|---|---|
| A ... ... ... ... | 132 | 53 | |
| B ... ... ... ... | 66 | 40 | |
| C ... ... ... ... | 33 | 20 | |
| D ... .. ... ... | 33 | 20 | |
| E ... ... ... ... | 66 | 40 | |
| F ... ... ... ... | 1,122 | 310 | 6·08 |
| G ... ... ... ... | 66 | 20 | |
| H ... ... ... ... | 86 | 33 | |
| I ... ... ... ... | 66 | 26 | |
| J ... .. ... ... | 792 | 330 | 3·84 |
| K ... ... ... ... | 660 | 3 | |
| L ... ... ... ... | 528 | 16 | |
| M ... ... ... ... | 79 | 33 | |

"Most of these outcrops belong to distinct bodies of ore; others of them may be connected together beneath the surface. Thus, outcrop F can be traced along the top of a ridge for a distance of four hundred yards, and then abruptly vanishes under the alluvials of the Medway Rivulet Valley. Upon the opposite side of the valley there are several bodies of ore exposed along an extension of the same line of outcrop."

"The ore-bodies are, for the most part, covered with a deposit of soil or ironstone débris, and it is in consequence often difficult to locate the exact line of junction between ore and country. The dimensions given above are only approximately correct. I am of opinion that the outcrops may cover, and may have been derived from, extensive pyrites lodes; and this would seem to have been the opinion of Mr. S. Stutchbury. However, a crosscut has been driven into deposit F, at a depth of one hundred feet, and the ore here contains no trace of pyrites."

The ore is described by Mr. Jaquet as consisting of an intimate mixture of limonite and hematite in varying proportions. Samples of the ore were analysed in the laboratory attached to the Department of Mines, and gave the following results :—

| | Metallic iron. % | Silica. % | Phosphoric anhydride. % |
|---|---|---|---|
| Bulk sample from face of main quarry | 55·80 | 7·45 | ·396 |
| Picked hematite ore ... ... ... | 57·54 | 5·90 | ·166 |
| " ... ... ... | 55·80 | 6·95 | ·063 |

A sample taken from a small band of magnetic ore in the quarry yielded at the rate of 65·22 per cent. of metallic iron, 3·90 per cent. of silica, and 0·51 per cent. of phosphoric acid. Pockets of manganese ore (pyrolusite) were also found in a few places.

The land upon which the ironstone occurs is part of the Coombing Park Estate, and is leased by Messrs. J. Links and Sons, of Carcoar, who have opened out a large face, forty feet high, upon the southern end of deposit F, and have worked in numerous smaller quarries. Their output of ore (for use as flux) during the last three years was as follows:—

| Year. | Amount. |
|---|---|
| 1898 (April to December) ... ... ... ... ... | 4,882 tons. |
| 1899 ... ... ... ... ... ... ... ... | 6,322 ,, |
| 1900 (January to May) ... ... ... ... ... | 5,800 ,, |
| | 17,004 tons. |

In the following table particulars are given of the quantities and assay value of the ore despatched from the mine during the year 1898:

| Month. | Quantity of ore despatched. | Assay Value. | |
|---|---|---|---|
| | | Metallic iron. | Silica. |
| | tons. cwt. | per cent. | per cent. |
| April ... ... ... | 214 12 | 57 | 6·2 |
| May ... ... ... | 308 14 | 59·7 | 6·7 |
| June ... ... ... | 581 1 | 59·7 | 6·7 |
| July ... ... ... | 461 13 | 59·5 | 5·8 |
| August ... ... ... | 872 4 | 59·5 | 6·7 |
| September ... ... | 677 13 | 59·9 | 6·0 |
| October ... ... ... | 624 11 | 58·5 | 5·3 |
| November ... ... | 569 4 | 59 | 7·0 |
| December ... ... | 572 11 | 58 | 6·0 |

"During 1899 no assays were made on behalf of Messrs. Links. The ore was sold at a uniform price and guaranteed to contain over 45 per cent. of metallic iron, this standard being subsequently reduced to 43 per cent. At present not more than one per cent. of the ore broken down from the face is rejected, and by exercising a little more care in this direction, I think, an ore could be supplied yielding about fifty per cent. of iron and not more than eight per cent. of silica."

The "phosphorus ratio" of the four samples collected by Mr. Jaquet was as follows:—

| | |
|---|---|
| 1. Bulk sample from face of main quarry ... ... ... | ·310 |
| 2. Picked hematite ore ... ... ... ... ... | ·125 |
| 3. ,, ,, ... ... ... ... ... | ·048 |
| 4. Magnetic ore .. ... ... ... ... ... ... | ·034 |

Phosphorus thus appears to be present in some of the samples in quantities that would render it unsuitable for the production of steel by the ordinary Bessemer process; but it has not yet been ascertained whether this objection applies to the bulk of the ore. The proportion of phosphorus is lower than is required in the basic Bessemer process; but this could be remedied by the addition of phosphoric slags or other ores rich in phosphorus.

*Quantity of Ore in Sight.*—On the assumption that the ore only extends to a depth of one hundred feet, and that a cubic foot of it weighs two hundred pounds, Mr. Jaquet estimates that—

| | | |
|---|---|---|
| Deposit F contains | ... ... ... | 2,364,000 tons |
| ,, J ,, | ... ... ... | 1,493,000 ,, |
| Total | ... ... ... | 3,857,000 tons |

As, however, the ore includes bands of slate and siliceous rock he reduces these figures by one-third, thus making the quantity that may be reasonably assumed to be in sight 2,571,000 tons, or enough to keep a blast furnace which could treat two thousand tons per week in blast for twenty-five years.

The quarries are less that a mile distant from the railway, so that in the event of there being a large demand for the ore a short connecting line could easily be constructed, and the ore delivered direct into the railway trucks. At present the contract price for quarrying is 1s. 6d. per ton, and for carting the ore to the railway siding 1s. per ton. The distance by railway to Lithgow is ninety miles, and the existing rate for conveyance of ore is 3s. 9d. per ton, so that allowing 2s. per ton for royalties, &c., the cost of delivering the ore at Lithgow would be about 8s. 3d. per ton. Mr. Jaquet makes the following estimate of the cost of treatment at Lithgow:—

| | £ | s. | d. |
|---|---|---|---|
| Calcining ore ... ... ... ... ... | 0 | 2 | 0 |
| Two and a quarter tons of ore at 8s. 3d. ... | 0 | 18 | 7 |
| One ton of coke at 15s. ... ... ... ... | 0 | 15 | 0 |
| Ten cwt. of limestone at 4s. per ton ... ... | 0 | 2 | 0 |
| Labour ... ... ... ... ... ... | 0 | 6 | 0 |
| Repairs ... ... ... ... ... ... | 0 | 2 | 0 |
| Sundries ... ... ... ... ... ... | 0 | 2 | 0 |
| | £2 | 7 | 7 |

Mr. Jaquet further states: "This estimate must only be regarded as a rude approximation; I think it probable that the iron (pig) could be produced for a little less than this amount. I have not taken into account interest upon the capital outlay necessary to erect a blast furnace."

*The Cadia Ironstone Beds.*—Probably the most extensive deposits of iron ore in New South Wales are those in the vicinity of Cadia, about fourteen miles S.S.W. of Orange, and about eleven miles from the Millthorpe Railway Station. They occur on Portions 37, 38, and 83, Parish of

Waldegrave, and Portion 147, Parish of Clarendon, County of Bathurst. The earliest mention of one of these deposits was made by the late Mr. S. Stutchbury, Geological Surveyor, who in July, 1851, reported as follows:—"In a gully or creek called the Waterfall, running into the Cadiangulong or Oaky Creek, at the western end of a section of 640 acres, forming lot 1, for sale May 7th, at Carcoar, and at the extremity of a mountain spur known as the Rocky Range, there is an immense mass of oxydulous iron, forming in one solid mass a precipitous waterfall of about sixty feet in height. In this mass of iron, especially in the joints, there is brilliant crystallised iron pyrites, with a small quantity of yellow copper ore, and traces of blue and green carbonates of copper. A few yards below the waterfall large masses of yellow ochreous iron gossan occur in the banks and bed of the creek. This gossan contains a considerable quantity of earthy green carbonate of copper, also plush-like malachite. Upon sinking a short distance into it on the eastern side, a rich lode of gray sulphuret of copper was found. In traversing the creek southwards, numerous indications of other lodes were visible, together with large masses of mundic."

Recently the occurrence was inspected by Mr. J. B. Jaquet, Geological Surveyor, who reported that there are three large outcrops of what is probably one and the same bed of iron ore. Of the two most easterly outcrops, at the Canoblas Copper Mine (the site referred to by Mr. Stutchbury), one covers an area of 3·68 acres, and extends up a hillside for a distance of nine hundred feet, being finally lost to view under a sheet of basalt which caps the crown of the ridge. The other outcrop is eleven hundred feet long, and covers an area of 3·84 acres. The deposits appear to be of a bedded character, showing distinct stratification lines, and having a general south-westerly dip.

About one and a half mile to the westward (Portions 83 and 147), on what is known as the Iron Duke Copper Mine, there is a third outcrop on a much larger scale; here, again the deposit shows distinct evidence of a bedded origin, and its depth is south-easterly, pointing to the probability of its being a continuation of the first mentioned ore bodies. It is exposed on the sides and summit of a spur for a distance of about three thousand feet, and Mr. Jaquet estimates its average thickness at eighty feet. The outcrop covers an area of about forty acres. The rocks both above and below the bed of iron-ore are augite andesites which are much altered, the augite crystals passing into uralite and chlorite, and the latter mineral into epidote, while at the same time, there is a considerable development of magnetite.

These important deposits are described as consisting of two classes of ore, viz. (1) oxidised or secondary ore, and (2) unoxidised or primary ore. (1) The oxidised ore originally contained a little pyrites, but has been desulphurised by the atmosphere. It consists of hematite (chiefly specular ore) and magnetite, and contains (according to Mr. Jaquet's samples) from 57 to 65 per cent. of iron, 5 to 15 per cent. of silica, and

·013 to ·015 per cent. of phosphorus. It is, therefore, suitable for the manufacture of steel by the ordinary Bessemer and other acid processes, and compares favourably with some of the best American ores.

(2.) The primary ore differs from the last mentioned only in containing a small quantity of iron pyrites, and, occasionally, some copper pyrites. In reference to this, Mr. Jaquet states :—"It may be found that the copper is mainly confined to certain parts of the deposit. I do not think the ore, as a whole, is likely to contain a high percentage of copper. Both sulphur and copper are objectionable ingredients in an iron ore. The former could, in a great measure, be got rid of by roasting, and, if the latter occurred in sufficient quantity, it might be leached out of the roasted ore, and recovered. It is quite possible that the ore may be found to resemble that which occurs at the famous Cornwall Mines in Pennsylvania, U.S.A., which contains considerable quantities of both sulphur and copper."

On the assumption that the bed of ore extends in the direction of its dip for half the distance it is exposed along its outcrop, and that a cubic foot of the ore weighs only 224 lb., Mr. Jaquet estimates that there are in the Canoblas Mine three million tons, and in the Iron Duke Mine thirty-six million tons of iron ore.

The ore being situated, at both places, upon hill-sides, could be cheaply exploited by quarries. It would be necessary to construct a railway between the deposits and the main western line, a distance of at least eleven miles. Mr. Jaquet further estimates that the cost of winning and transporting the ore to the Lithgow Coal-field, a distance of ninety-five miles, should not exceed ten shillings per ton, nor the cost of smelting £2 10s. per ton of pig-iron produced. He adds, "It may be found advantageous to smelt the Cadia and Carcoar ores together. In this connection I may mention that recent analyses seem to indicate that a considerable quantity of ore could be obtained from Carcoar, either of Bessemer quality, or containing so slight an excess of phosphorus as to enable it to be blended with other ores low in phosphorus, and utilised in the production of Bessemer pig-iron; but until further analyses are to hand, I cannot speak definitely upon this subject. The manganese present in the Carcoar ores would form a valuable addition to a furnace charge high in sulphur."

In summarising his observations on the Cadia deposits Mr. Jaquet states as follows :—"A large proportion of this ore is of Bessemer quality, *i.e.*, could be used for producing steel by the cheaper acid processes. There is, in sight, a large quantity—at least one million tons—of oxidised ore which, as regards quality, will compare favourably with the Lake Superior and other American high-grade ores."

"At a varying depth below the surface the oxidised ore will give place to an ore consisting essentially of magnetite and hematite, with a little pyrites, and containing appreciable quantities of copper; but, having regard to the results obtained elsewhere, the presence of these substances will not necessarily prevent the ore being employed in the production of steel; more particularly if it be smelted with ores obtained from other localities, which are practically free from copper and sulphur."

*Port Stephens Ironstone Deposits.*—A bed of magnetite occurs in the Ironstone Mountain, about three miles west of the Karua Wharf, on the Karua River, an arm of Port Stephens. This deposit was examined and reported upon in 1889 and 1891 by Mr. T. W. E. David, Geological Surveyor, on whose recommendation a sum of money from the Prospecting Vote was expended in testing it. The outcrop of the bed of magnetite was found to have an average thickness of three feet for a distance of thirty chains; its average dip is 20° for a distance of at least 440 yards, at which limit the bed would probably be about 450 feet below the surface. It was calculated from these data that, within an area of sixty acres, the bed would contain, approximately, 876,000 tons of ore, containing, on an average, 45 per cent. of metallic ore. Samples of the ore from six portions of the bed were analysed by Mr. Mingaye, with the following result:—

| | |
|---|---|
| Moisture at 100° C. ... ... ... ... ... ... ... | ·67 |
| Combined moisture ... ... ... ... ... ... ... | 3·31 |
| Iron peroxide ($Fe_2O_3$) ... ... ... ... ... ... | 52·86 |
| Iron protoxide ($FeO$) ... ... ... ... ... ... | 7·79 |
| Alumina ... ... ... ... ... ... ... ... | 5·21 |
| Silica ... ... ... ... ... ... ... ... ... | 18·70 |
| Iron peroxide (insoluble) ... ... ... ... ... ... | ·75 |
| Lime ... ... ... ... ... ... ... ... ... | 1·12 |
| Titanic acid ... ... ... ... ... ... ... ... | 7·30 |
| Carbonic acid ... ... ... ... ... ... ... ... | 1·60 |
| Manganese protoxide, magnesia, organic matter, phosphoric acid, sulphuric acid ... ... ... ... ... ... | traces. |
| | 99·31 |

It was evident that the high percentage of titanic acid, and also the rather large amounts of silica and alumina which are present in the ore, would prevent its being profitably worked. Although titanium has not an injurious effect upon the quality of the metal, its presence in such quantity in the ore would render it very difficult to smelt, and, therefore, this deposit cannot, at the present time, be considered of much importance in estimating the quantity of iron ore available in the Colony for smelting works. A number of other deposits of magnetite in the Williams River and Port Stephens Districts have been examined and mapped by Mr. J. B. Jaquet, Geological Surveyor. They occur as lenticular masses in the *Rhacopteris* Beds of the Carboniferous Formation. As many as twenty-five of these masses were examined, but in no case were they found to be continuous for any great distance either horizontally or in the direction of their dip, which was conformable with that the enclosing *Rhacopteris* Beds. The total quantity of iron ore in the districts was estimated not to exceed 2,000,000 tons. Twenty-five analyses were made of ore from different beds, and the mean of these gave the following results :—

| | |
|---|---|
| Metallic iron ... ... ... ... | 44·40 per cent. |
| Silica ... ... ... ... ... | 17·91 ,, |
| Titanic acid ... ... ... ... | 8·21 ,, |
| Phosphoric anhydride ... ... ... | 0·258 ,, |

It is evident, therefore, that these deposits, like that of Ironstone Mountain, are of no immediate commercial importance, as the quantity of titanic acid present would render them too refractory for smelting purposes, and, moreover, the percentage of silica is also too high.

Deposits of bog-iron ore are known to exist at several localities in the Southern Coal-field, as, for instance, at Jamberoo, to the west of Kiama, where the deposits overlie the Hawkesbury Sandstones, and also in the vicinity of Jervis Bay. So far as is at present known, these deposits are not of any great extent, but there is a possibility that others of more importance may yet be discovered.

Allusion has only been made to those deposits of iron ore which are known to exist within a reasonable distance of supplies of coal, and in connection with which, therefore, the conditions are favourable to economic treatment. Iron ores, however, also occur in many other localities in New South Wales, where facilities do not at present exist for profitably smelting them. For instance, a deposit of specular iron ore at Mount Gobondery, near Fifield, was examined in 1898 by Mr. J. A. Watt, Geological Surveyor. He estimated that there are, in this locality, about 8,000 tons of ore in sight containing an average of 59·33 per cent. of metallic iron, and the surface indications point to the probability that, if prospected, the deposit would prove to be of large dimensions, as the various outcrops are separated by considerable areas of surface soil which may cover extensions of the deposit.

Another large deposit of iron ore is known to occur near the junction of the Cotter and Murrumbidgee Rivers, about twenty miles to the west of Queanbeyan. It consists of magnetite and probably contains about one million tons, but its distance from the nearest workable deposits of coal would prevent its competing with some of the more favourably situated ore bodies already referred to.

Considerable quantities of iron peroxide are used as a flux by the various smelting works in New South Wales, and there has also been for some years past, a regular export of this material for use in gas works in the other Australian Colonies and New Zealand; the particulars of the iron exported for the latter purpose are given in the accompanying table.

Peroxide of Iron exported for use in Gas Works in other Colonies.

| Year. | Quantity. | Value. |
|---|---|---|
| | tons. | £ |
| 1885 ... ... ... | 449·95 | 1,569 |
| 1886 ... ... ... | ............ | ... ........ |
| 1887 ... ... ... | ............ | ...... ... ... |
| 1888 ... ... ... | ............ | ............ |
| 1889 ... ... ... | 489·05 | 1,329 |
| 1890 ... ... ... | 455·30 | 884 |
| 1891 ... ... ... | 228·75 | 434 |
| 1892 ... ... ... | 453·15 | 869 |
| 1893 ... ... ... | 1,259·95 | 1,526 |
| 1894 ... ... ... | 432·90 | 670 |
| 1895 ... ... ... | 152·35 | 348 |
| 1896 ... ... ... | 375·40 | 801 |
| 1897 ... ... ... | 230·05 | 536 |
| 1898 ... ... ... | 391·95 | 832 |
| 1899 ... ... ... | 396·35 | 846 |
| Totals ... ... | 5,315·15 | 10,644 |

# ALUMINIUM.

Although aluminium has not as yet been manufactured in the Colony, it is satisfactory to know that the ores from which it is chiefly made in other countries occur in great abundance in New South Wales, and in view of the great reduction which has been brought about in the price of the metal (48s. per lb. in 1886 to 1s. 3d. in 1898), and its correspondingly increased use in manufactures, there can be little doubt that the aluminium-smelting industry will be established in this part of the world before long.

All clays are composed mainly of hydrous silicate of alumina, and these are of common occurrence; however the cost of the production of aluminium from clay is too great to allow of the latter substance competing with some other minerals as a source of the metal.

*Bauxite.*—Hydrous sesquioxide of aluminium. $Al_2 O_3 2H_2O$; contains when pure 73·9 per cent. of alumina (39·3 per cent. of the metal), and 26·1 per cent. of water. Sesquioxide of iron is usually present, sometimes up to 50 per cent., in part replacing alumina, in part as an impurity. Silica, phosphoric acid, carbonic acid, titanic acid, lime and magnesia also occur as impurities. There are two varieties known, viz., (1) *bauxite*, which is pisolitic or oolitic in structure, and (2) *wocheinite*, which is massive, earthy, or claylike. Specific gravity, 2·55; colour, whitish, grayish, yellowish, brown, and red. The mineral bauxite is named after the district Baux, in France, where it was first discovered. Found in the Emmaville, Inverell, and Wingello Districts.

The occurrence of bauxite in New South Wales was not known until 1899, when it was recognised by Mr. Geological Surveyor Jaquet at Wingello, in the County of Camden, where he found it occupying considerable areas. Almost simultaneously it was detected in extensive deposits in the Inverell and Emmaville Districts. At Emmaville, in 1886, Mr. T. W. E. David, when making a geological survey of the tin-mining field, found that twelve square miles of country were covered by deposits of laterite or volcanic ash, from a few feet up to forty feet in thickness, and this material now proves to be *bauxite* and *wocheinite*, for it occurs both in the pisolitic and massive forms. In the Inverell District, also, it is now known to occupy very considerable areas. Its mode of occurrence is similar in both districts; it is frequently roughly stratified, and is generally found capping small hills, in many cases surrounding points of eruption. It is clearly of volcanic origin, and while in some cases it appears to consist of volcanic ash, in others it may have been derived from the decomposition of basalt *in situ*. In colour the New South Wales bauxite varies from pale yellow to deep red. Near Inverell it has been extensively used for making roads, with very satisfactory results.

With the exception of those near Emmaville, none of the deposits of bauxite have been mapped, nor has any definite attempt as yet been made to classify the ores on the basis of their alumina contents. A few samples of the ore of different colours have been submitted for analysis, and the results are tabulated below. It will be noticed that the proportions of alumina and iron are very variable, and that phosphoric acid and titanic acid are always present in greater or less amounts. For the sake of comparison, analyses of a number of samples of European and American bauxites are appended; at the same time, it is necessary to bear in mind that nothing in the shape of a systematic examination of the New South Wales deposits has yet been made, and therefore too much value must not be placed upon these analyses as representative of either their richness or poverty in bulk :—

Analyses of New South Wales Bauxites.

| Locality. | Alumina. | Water. | Ferric oxide. | Silica. | Lime. | Magnesia. | Soda and Potash. | Phosphoric Acid. | Titanic Acid. |
|---|---|---|---|---|---|---|---|---|---|
| Eastern end of Portion 151, Parish Wingello, County of Camden. | 37·31 | 20·65 | 29·42 | 9·12 | ... | ... | ... | ·01 | present. |
| Centre of Portion 151, Parish Wingello, County Camden. | 34·14 | 22·40 | 36·53 | 3·14 | ... | ... | ... | ·088 | present. |
| Portion 19, Parish Bumballa, County Camden. | 49·64 | 6·85 | 32·41 | 7·10 | ... | ... | ... | ·153 | present. |
| North-east end Portion 16, Parish Bumballa, County Camden. | 32·82 | 19·20 | 27·18 | 17·80 | ... | ... | ... | ... | present. |
| 3 miles east of Barber's Creek Railway Station. | 34·07 | 12·78 | 42·21 | 16·24 | ·36 | ·18 | ·28 | ·17 | 4·45 |
| South-west of Portion 34, Parish Caoura, County Camden. | 45·82 | 20·26 | 18·70 | 12·22 | ... | ... | ... | ... | present. |
| Portion 101, Parish Murrimbah, County Camden. | 61·46 | 30·77 | 1·99 | 1·90 | ... | ... | ... | ·08 | present. |
| Do do | 39·47 | 23·68 | 31·55 | 1·30 | ... | ... | .. | ... | present. |
| 8 miles south of Inverell.... | 33·89 | 18·88 | 30·25 | 15·80 | ... | ·14 | ·38 | ·19 | ·55 |
| Warialda road, 9½ miles from Inverell. | 41·68 | 26·34 | 24·18 | 4·10 | ·80 | ·14 | ... | ·23 | 2·05 |
| Warialda road, 5 miles from Inverell. | 38·97 | 24·79 | 28·65 | 1·70 | ·50 | ·18 | ... | ·37 | 4·35 |
| 5 miles north of Inverell ... | 31·43 | 20·38 | 27·06 | 15·01 | ... | ·40 | ... | ·34 | 4·98 |
| Near Wingello ... ... | 58·31 | 32·68 | 2·85 | 1·80 | ... | ... | ... | ·66 | 2·40 |
| Do do ... ... | 35·28 | 17·81 | 12·90 | 29·80 | ... | ... | ... | ·19 | 2·65 |
| Do do ... ... | 39·82 | 22·30 | 20·34 | 10·30 | ... | ... | ... | ·56 | 5·50 |
| Emmaville (red ore) ... | 42·20 | 23·45 | 28·91 | ·16 | ·28 | ·37 | ·17 | ·26 | 4·75 |
| Do (mottled ore)... | 47·84 | 19·23 | 13·59 | 16·40 | ·74 | ·23 | ·20 | ·14 | 1·77 |
| Do (yellow ore) ... | 28·96 | 15·51 | 16·20 | 35·56 | ·50 | ·31 | ·20 | ·05 | 2·98 |

Analyses of Foreign Bauxites (*Mineral Industry*).

| | Alumina. | Water. | Ferric Oxide. | Silica. | Carbonate of Lime. | Titanic Acid. | Potash and Soda |
|---|---|---|---|---|---|---|---|
| France ... | 30·30 | 22·10 | 34·90 | ...... | 12·70 | ...... | ...... |
| | 33·20 | 8·60 | 48·80 | 2·00 | ...... | 1·60 | ...... |
| | 69·30 | 14·10 | 22·90 | 0·30 | ...... | 3·40 | ...... |
| | 76·90 | 15·80 | 0·10 | 2·20 | ...... | 4·00 | ...... |
| Ireland ... | 48·12 | 40·33 | 2·36 | 7·95 | ...... | ...... | ...... |
| | 43·44 | 35·70 | 2·11 | 15·05 | ...... | ...... | ...... |
| | 61·89 | 27·82 | 1·96 | 6·01 | ...... | ...... | ...... |
| | 73·00 | 18·66 | 4·26 | 2·15 | ...... | ...... | ...... |
| Germany ... | 44·40 | 9·70 | 30·30 | 15·00 | ...... | ...... | ...... |
| | 54·10 | 23·90 | 10·40 | 12·00 | ...... | ...... | ...... |
| | 72·87 | 8·50 | 13·49 | 4·25 | ...... | ...... | 0·78 |
| | 29·80 | 13·86 | 3·67 | 44·76 | ...... | ...... | ...... |
| America (Georgia). | 44·37 | 26·80 | 3·53 | 22·95 | ...... | 2·35 | ...... |
| | 82·38 | 13·35 | 1·63 | 1·62 | ...... | ...... | ...... |
| | 31·96 | ...... | ...... | ...... | ...... | ...... | ...... |
| | 20·02 | ...... | ...... | ...... | ...... | ...... | ...... |
| (Alabama).. | 39·44 | 12·80 | 2·27 | 37·87 | ...... | ...... | ...... |
| | 41·00 | 21·97 | 25·25 | 10·25 | ...... | ...... | ...... |
| | 62·00 | 30·00 | 1·00 | 2·50 | ...... | ...... | ...... |
| | 61·00 | 31·58 | 2·20 | 2·10 | ...... | 3·12 | ...... |
| | 44·81 | 17·28 | 1·37 | 33·94 | ...... | 2·00 | ...... |
| | 51·90 | 24·86 | 3·16 | 16·76 | ...... | 3·50 | ...... |
| | 58·60 | 28·63 | 9·11 | 3·34 | ...... | ...... | ...... |
| | 62·05 | 30·31 | 1·66 | 2·00 | ...... | 3·50 | ...... |

*Uses of Bauxite.*—The following information in regard to the uses of bauxite is taken from an article by Professor Henry McCalley, in *The Mineral Industry*, 1893:—"The ore was used when first discovered, before its true character was known, both in this country (the United States of America) and in Europe, for an iron ore, but it was soon found to be too refractory for this purpose. It was used in Arkansas as a road material. It is now considered, however, the most valuable and most desirable of all minerals that can be gotten in large enough quantities for the manufacture in commercial quantities of metallic aluminium and its alloys and compounds.' Before being used for any of these purposes, however, it is purified, *i.e.*, its soluble alumina is separated out from the impurities present by one of two processes, known as the sulphuric acid and the sodium carbonate methods. The ore is comparatively soft, and easily manipulated. It gives metallic aluminium, of almost perfect purity, at a very reasonable cost, and has been used in the manufacture of aluminium and aluminium alloys since 1885."

"The principal use of bauxite, however, is for the manufacture of aluminium salts, or compounds, especially alums, which are used largely in manufacturing paper, dyes, and baking powders. Another salt that is also extensively manufactured from it is aluminate of soda, which is used in large quantities in dyeing and calico-printing. The greatest value and use of the ore in the future, it is believed, will be for the manufacture of the highest grade refractory materials, like crucibles and firebrick. The better class of ores should be kept for this purpose, while those of inferior quality could be converted into alum and other compounds. An ore carrying as much as 10 per cent. of ferric oxide, and 20 per cent. of silica, can be easily used for the manufacture of alum."

"Another important and remunerative use for bauxite is now claimed in the preparation of aluminò-ferric cake, a cheap by-product employed for the purification and deodorization of sewage, and for making, at the same time, valuable fertilizers of their foul and evil smelling effluents. This discovery, it is claimed, has been shown on the Thames and Clyde to be especially adapted to the cleaning of rivers and large streams, and will no doubt come into general use."

When bauxite is used as an ore of aluminium, it is first necessary to prepare pure alumina from it. This is generally done by fusing it with sodium carbonate, or boiling it with a strong solution of caustic soda, whereby aluminate of sodium is formed; this is leached out with water, and carbon dioxide is passed through the solution, thus precipitating aluminium hydrate, which is then converted into alumina by heating.

The manufacture of alumina from bauxite at Larne, Ireland, by the Bayer process, is described by Mr. J. Sutherland (*Mining and Engineering Journal*, Oct. 3rd, 1896). According to this Writer, the raw material is bauxite, from County Antrim, averaging 56 per cent. $Al_2O_3$, 3 per cent. $Fe_2O_3$, 12 per cent. $SiO_2$, 3 per cent. $TiO_2$, and 26 per cent. $H_2O$. It is crushed to pass a $\frac{1}{4}$ in. sieve, and calcined in an Oxland and Hocking cylinder, an excessive temperature being avoided lest the alumina be rendered insoluble. The calcined mineral is treated with caustic soda solution, of 1·45 specific gravity in pressure kiers made of $\frac{5}{8}$ inch steel plates, 11 feet long and 5 feet in diameter, a 3 inch horizontal shaft with eight 16 inch by 9 inch paddles (agitators) passing through stuffing-boxes in the ends. The soda solution is first introduced, and the ore (about 3 tons) is added subsequently, the paddles being in motion to secure thorough mixture. After closing the charge door steam is turned on, and the pressure raised gradually to 70 or 80 lbs., at which it is maintained two hours, when decomposition is complete. The discharge cock being opened, the mud and solution are raised to tanks at the top of the building by the pressure in the kier. Water is added to reduce the specific gravity of the liquid to 1.23, and the solution of sodium aluminate is separated by means of filter presses, the residue being washed and thrown away. The solution is filtered again through wood pulp contained in lead-lined vats, 10 by 6 by 3 feet, the filter being placed 6 inches above the bottom. The filter consists of an $\frac{1}{8}$ inch screen, on which is run a thin paste made by boiling 50 lbs. of wood pulp with water. The pulp soon settles evenly over the sieve, forming the filter proper. The sodium aluminate solution, having been purified, is run into tanks 13 feet in diameter, and 20 feet deep, provided with agitators. The precipitation of aluminium hydrate is effected by an excess of the same substance. Within thirty-six hours' agitation 70 per cent. of the alumina is precipitated. The precipitate is then allowed to settle, and the supernatant liquor is then drawn off to storage tanks, after which the precipitate is removed and pressed, enough being left in the vat to precipitate the next lot of solution. The pressed cakes having been washed free from soda, air at 80 lbs. pressure is forced through them to drive out as much water as possible, and they are finally burned at 2,000° F. A lower temperature is, of course, sufficient to dry them, but at this high heat the alumina becomes crystalline, in which state it is less prone to absorb moisture from the air. The weak liquor from the precipitating vat, having a specific gravity of 1·2, is brought up to 1·45 specific gravity in triple-effect evaporators, and used to decompose calcined bauxite.

Another method of obtaining alumina from bauxite is to treat the mineral with sulphuric acid until the alumina is dissolved. The solution is then filtered and evaporated to dryness, and the sulphate of alumina thus obtained is ignited.

In America the bauxite is dried in kilns or roasting furnaces at the mines before being forwarded to the works. This is done in order to avoid freight on the large proportion of water contained in the ore.

*Metallurgy of Aluminium.*—The process now generally adopted for the production of the metal aluminium consists in the electrolysis of a fused bath of cryolite, in which alumina (prepared by one of the methods just described) has been dissolved. Cryolite is a mineral consisting of fluorides of sodium and aluminium, and is found in quantity in only one locality, viz., in Southern Greenland. The following quotation is from an article by Mr. H. N. Yates, in *The Mineral Industry*:—"The electrolytic is the only method for the manufacture of pure aluminium being carried on at the present day. In this country (United States), and in England, the Cowles and Hall processes are used, and on the Continent the Héroult and Minet; but as carried out they are all practically the same, viz., a modification of the old Deville-Bunsen process, employing, however, the heat of the current to maintain the fusion. A brief description of the operation of one will suffice for all, so far as concerns the essential principles.

"The furnace is a rectangular iron box, open on top, and lined on the inside with a thick carbon bottom and walls. The whole furnace is made the negative electrode, and is connected with the dynamo by means of heavy copper rods. The anode consists of a number of carbon cylinders, 3 inches in diameter by from 14 to 20 inches long, clamped to and suspended from a copper bar running parallel to the axis of the furnace, and a few feet above it. In practice several of the furnaces are connected in series, their number depending directly on the current generated by the dynamo. For instance, a current of 50 volts and 3,000 amperes will supply a series of six furnaces, thus giving each furnace about 8 volts and 3,000 amperes, which is about the strength of current required for the operation."

"To start a furnace the carbon cylinders are lowered till they touch the carbon bottom. A poor contact is thus formed, and the ground cryolite, which is then piled around the carbons, is melted by the resistance. When enough has been melted to form a good bath the carbons are raised, and the melted cryolite carries the current and becomes the electrolyte. The resistance is very high until alumina is added to the bath and dissolved there, when it falls suddenly, and the difference of potential between the electrodes becomes constant at from 6 to 10 volts. A sudden rise in voltage indicates, therefore, very clearly when the alumina has been all reduced, and when more must be added. The process is continuous, day and night, seven days a week. The metal which collects in the bottom of the furnace is removed every 24 hours. The metal made by this process is very pure, most of it running above 99 per cent. aluminium, and by using extra pure materials it may be made to approximate very nearly to 100 per cent."

The Pittsburg Reduction Company of America produced 6,500,000 lb. of aluminium in 1899. This company has works at New Kensington, Pennsylvania, and at Niagara Falls, New York, and it controls the manufacture of this metal in the United States. In Great Britain, the production of aluminium is in the hands of the British Aluminium Company, at Foyers, Scotland; on the continent of Europe the Aluminium Industrie Actien-Gesellschaft, of Neuhausen, Switzerland, is the principal producer, while in France there are small works at La Pratz and St. Michel.

*Uses of aluminium.*—The following extracts are taken from a paper by Mr. E. Ristori, read before the Institution of Mechanical Engineers, at Derby, in July, 1898:—"The principal uses of aluminium are too many to be enumerated. The properties of the metal are so akin to those of copper and brass that, broadly speaking, aluminium or one of its light alloys should, to a large extent, replace both copper and tin, and also nickel or German silver. Such a change would be followed by various advantages to all concerned. Not only would there be a considerable reduction in the weight of the articles, but they would not tarnish or turn black on exposure to air. The cost should be the same, if not actually lower, inasmuch as, bulk for bulk, aluminium is already cheaper than copper or tin; and its price will continue to fall as the demand increases. One field, however, remains, which copper is bound to maintain as its own, namely, the construction of insulated electrical conductors. Experiments have already been made on a large scale with bare conductors of aluminium for telephones, &c.; and the British Aluminium Company are using it in this manner at their Foyers Works with perfectly satisfactory results, its conductivity, weight for weight, being double that of copper. But when the mains have to be insulated, copper is absolutely unapproachable, on account of its greater conductivity, volume for volume, which is 165 per cent. of that of aluminium. Besides the advantages set forth above, aluminium is not poisonous, and is pre-eminently adapted for the manufacture of cooking utensils. On the other hand, tinware is not particularly cheap in the long run, for it is constantly wearing out; cast-iron is heavy and brittle; and copper requires to be frequently re-tinned in order to avoid all danger to health. Inasmuch as an aluminium saucepan costs no more in the first instance than a copper one, weighs much less, is perfectly innocuous, and does not periodically need a fresh inside, it is not surprising that the employment of aluminium in kitchens and canteens is spreading rapidly."

"A steady demand for aluminium is springing up in various kinds of printing processes, as well as in lithography. The metal appears to answer admirably for the construction of rollers used in calico-printing; and when its surface is properly prepared, it is also capable of replacing the ordinary lithographic stone. It can easily be imagined that, instead of having cumbrous and heavy stones, which can be printed only on special slow-running 'litho' machines, it is far better and cheaper to use thin sheets of a metal which can be bent into a circular form and printed on rotary presses."

"Bicycles of all kinds, electric light fittings, chains, bridles, stirrups, surgical instruments, sextants and other scientific apparatus, keys, cigar cases, pen and pencil holders, toilet articles, plates and dishes, spoons, forks, frames, name-plates, door furniture, hat and coat pegs, boot trees, fire-engine fittings, business and visiting cards, photographic cameras, &c., are a few of the things that are being daily made in aluminium by various firms; and all these articles should be sold at the same price as if they were composed of brass."

"There are other instances where aluminium should economically replace commoner metals than copper or brass. Wherever a great deal of dead weight has to be continually moved about, the cost of motive power, for which there is apparently no return, is serious; and if this unremunerative weight can be reduced to one-third of its present amount, in the course of a year or two the saving in power will more than compensate for the greater initial outlay. Thus frames for cabs and motor cars have already been made in aluminium; and though in England experiments have not yet been tried in this direction, aluminium railway carriage frames are under review in France. Especially for motor cars should there be a large field here for aluminium. A further demand for the metal will be brought about by its introduction into the military services. All parts of the soldiers' equipment have practically been made already in aluminium; such as mess tins, water bottles, buttons, helmets, parts of rifles, cartridge cases, fittings for guns, tents, horse shoes, portable bridges, &c. Nothing much has yet been done in England in this direction; but it is well known that continental armies, notably that of Germany, are employing aluminium on a large scale."

"One of the largest uses to which aluminium has been applied is in metallurgy, where its valuable metallurgical properties were discovered and utilised. It is common knowledge among steel-makers that ingots often turn out spongy at the top; and when particularly good ingots are required, the faulty portion is cut off and melted over again. By the addition of a very small portion of aluminium to iron, steel, or brass, either in the mould or in the ladle, the founder can be quite certain that the ingots will be solid all through. When used in this way aluminium has the peculiar virtue of instantly liberating all the gases contained in the metal, and of keeping it fluid for a longer period, so that by the time the casting solidifies the gases have had an opportunity to escape. In almost all steel works, and in all the principal foundries, aluminium is now being employed; and reports from some of these state that the result is a reduction in the wasters by 80 or 90 per cent. In this case aluminium does not actually replace any other metal, but by its own special qualities is useful as a means of improving physically and chemically some of its older rivals and friends."

"The use of aluminium in shipbuilding is growing rapidly, on account of the almost inestimable advantage of its great saving in weight. Four or five years ago a small canoe was made on the Thames of two sheets of aluminium stamped and riveted together. In 1892, Messrs. Escher Wyss, of Zurich, constructed a small launch entirely of aluminium, driven by a naphtha motor; and in the following year they built for Mr. Nobel another larger vessel, which has been in use ever since, and is now on one of the Swedish lakes. During 1894 and 1895 the author had on the Thames, between Windsor and Maidenhead, a similar vessel, which is now at work at Foyers. A much more ambitious attempt was made by Messrs. Yarrow in 1894. By request of the French Government they built of aluminium the whole of a second-class torpedo boat, 60 feet long by 9 feet 3 inches beam. This boat weighed in full working order, but exclusive of armament, only 9½ tons; and attained during a run of two hours, carrying a load of 3 tons, and with engines indicating about 300 H.P., a mean speed of 20½ knots—an advance of 3½ knots over all previous records. Several yachts, including the *Vendenesse*, were also constructed at the same time, but they do not seem to have been a real and permanent success, owing probably to the adoption of an unsuitable alloy. As pure aluminium was not strong enough alone, it was thought better to use an alloy containing about 6 per cent. of copper in the construction of some of these boats. This alloy possesses a tensile strength of 14 tons per square inch; but, as already stated, this material is absolutely untrustworthy in sea water, owing to the rapid corrosive action set up between its two ingredients. Moreover, although nobody would dream of employing any other metal than copper for plating sea-going vessels unless it were afterwards painted, aluminium has always been used bare, which the author considers a mistake. If the aluminium had been protected from direct contact with the water, it would have lasted much better. Unfortunately this comparative failure has materially discouraged the adoption of aluminium in ship-building; and although it is now well recognised that the pure metal, and several of its alloys which do not contain copper, stand the action of salt water better than iron or steel, some time is likely to elapse before these premature tests are forgotten. Eventually, however, when further experiments have been carried out, there is no reason why a suitable alloy should not be adopted, which, when properly used and protected from direct contact with sea water, would resist corrosion as the majority of materials now employed in ship-building. These remarks refer only to the keel and other parts of the vessel below water, and chiefly to such craft as are to navigate the open sea."

"For all internal work aluminium is perfectly safe; and it is specially suitable for adoption in the Navy, where the presence of wood and other inflammable material should be discouraged as much as possible, lest it lead to fires during action. In all boats sailing on fresh or inland waters the corrosion is less; and when portability is desired, as in the case of expeditions to little-known parts of the world, even if the aluminium do suffer corrosion, this is of trifling moment in comparison with the advantage of smaller weight to be transported. For instance, Messrs. David White, of Glasgow, have recently constructed an 18-foot boat for a party going to Klondyke, weighing only $1\frac{3}{4}$ cwt., which is wholly composed of aluminium, even to rivets, nails, bolts, and nuts. It is made in sections, which pack into one another, and the whole can be put into a box. Messrs. Forrest and Son, of Wivenhoe, have also furnished a flotilla of two launches and a barge for Major Gibbons' trans-African expedition, which started in May. The vessels are built in sections, on the Hodgetts' principle, each piece measuring about 6 feet 6 inches by 3 feet 9 inches, and weighing less than 120 lb., so that two natives can easily carry one between them by means of oars on their shoulders. The chief peculiarity of these boats lies in the interchangeability of the twenty sections composing the fleet. The different pieces can be put together in a variety of ways, forming three separate boats of such sizes as may be most convenient at the moment. It is possible to have either two 26-foot launches and one $22\frac{1}{2}$-foot barge, or one $44\frac{1}{2}$-foot launch and two 15-foot barges; or one 37-foot launch, one $22\frac{1}{2}$-foot barge, and one 15-foot barge, &c. One launch is fitted with an awning; the other carries a mast and sail."

# COBALT AND NICKEL.

As cobalt and nickel are generally found associated with one another in the same minerals, the two metals will be referred to under the same heading. Although traces of both nickel and cobalt have beenfound in numerous localities in New South Wales, they are not at present known to occur in anything like workable quantities in more than two or three places, and consequently the export of these metals has, so far, been small.

The following is a list of the cobalt and nickel minerals hitherto found in New South Wales :—

*Psilomelane or wad*—Hydrous manganate of manganese, containing oxides of cobalt and nickel in variable quantities. $H_2MnO_5$ ; hardness, 5—6 ; specific gravity, 3·7—4·7 ; massive, botryoidal, and stalactitic; colour, iron-black, passing into steel-gray. Is of very common occurrence, being found in the palæozoic and eruptive rocks in a great many localities.

*Kupfermanganerz*, containing a small percentage of cobalt oxide, has, according to Professor Liversidge (" Minerals of New South Wales"), been found in the Coombing Copper Mine, also on Wiseman's Creek, near Soldier's Hill.

*Glaucodot*—Sulph-arsenide of cobalt and iron. (Co, Fe) AsS ; hardness, 5 ; specific gravity, 5·9—6·01 ; fracture, uneven, brittle ; colour, grayish tin-white; streak, black ; contains 23·8 per cent. of cobalt. Found at Carcoar.

*Cobaltite*—Sulph-arsenide of cobalt ; $CoS_2$ $CoAs_2$ ; contains 35·5 per cent. of cobalt. Fracture, uneven, brittle ; colour, silver-white, inclined to red; also steel-gray, with a violet tinge, or grayish-black when containing much iron; streak, grayish black; hardness, 5·5; specific gravity, 6-6·3. Found in the Australian Broken Hill Consols Mine.

*Willyamite.*—Sulph-antimonide of cobalt and nickel, $CoS_2$ $NiS_2$ $CoSb_2$ $NiSb_2$. Contains 13·9 per cent. of cobalt, and 13·4 per cent. of nickel by analysis; fracture uneven, brittle; colour between tin-white and steel-gray ; streak, grayish-black ; hardness, 5·5 ; specific gravity, 6·87. Found in the Australian Broken Hill Consols Mine.

*Kupfernickel.*—Arsenide of nickel, NiAs. Contains 43·9 per cent. of nickel; usually massive; colour, pale copper-red, with a gray to blackish tarnish ; hardness, 5–5·5 ; specific gravity, 7·33–7·67. Found by the Rev. W. B. Clarke on the Peel River, near Bowling Alley Point.

*Millerite.*—Sulphide of nickel, Ni S. Contains 64·6 per cent. of nickel ; usually in slender capillary crystals ; colour, brass-yellow ; hardness, 3–3·5 ; specific gravity, 5·3–5·65. Found by the late Mr. Rauft in a quartz reef about three miles from Elsmore.

*Erythrine.*—Cobalt bloom ; hydrous arseniate of cobalt, $Co_3As_2 O_8 + 8\ H_2O$. Contains 37·5 per cent. of protoxide of cobalt ; sectile ; colour, crimson and peach-red, sometimes pearl-gray or greenish-gray, streak a little paler than the colour. Found at the Australian Broken Hill Consols Mine, and also at Carcoar.

*Annabergite.*—Nickel bloom ; hydrous arsenate of nickel, $Ni_3As_2 O_8 + 8H_2O$. Contains 37·4 per cent. of nickel. Soft, fracture earthy ; colour, apple green. Found at Carcoar.

*Nickeliferous Opal.*—Mr. D. A. Porter, of Tamworth, has recorded the occurrence of veins of green nickeliferous opal in serpentine rock in the Never Never Ranges, on the head waters of Attunga Creek, and not far distant from Mount Gulligal, Parish of Attunga, County of Inglis. The veins of opal are from $\frac{1}{16}$ to $\frac{1}{2}$ inch thick, and are accompanied by veins of a pinkish or salmon coloured chalcedony. The opal gave strong reactions for nickel.

## Cobalt.

The World's production of cobalt is about 200 tons per annum. Its principal use is in the manufacture of a beautiful blue pigment, which is largely used for tinting glass and porcelain.

## Nickel.

The following statement of the uses of nickel is taken from Rothwell's *Mineral Industry*, Vol. I, 1892 :—"The great increase in the demand for nickel during the past two years has been due to the large purchases of the United States Government for the manufacture of nickel-steel armour plate, the reported decision of the French Government to plate certain parts of its military rifles with nickel, and the large contract given by the Austrian Government for nickel for coinage. Another new channel of consumption—and an important one—is the manufacture of a nickel-copper alloy (Ni 20%, Cu 80%) for casing bullets to be used with small-bore rifles now adopted by all the armies of Europe. This alloy has a higher degree of tenacity then the best brass, combined with a high coefficient of elongation. At the same time there has been the natural increase in the demand for nickel for use in the arts."

"In this connection it should be noted that American nickel-steel plates have recently been tested by the Russian Government at its proving ground at Ochta, near St. Petersburg, with very satisfactory results; and from the last report of the Chief of Engineers of the United States Navy, it is probable that experiments will be made this year to determine the utility of nickel-steel in the construction of propeller-shafts and certain parts of the engines for the new men-of-war that are now being built."

*Ibid.*, Vol. II, 1893.—"The extent to which nickel is coming into use in Europe for small articles which have hitherto been only nickel-plated, is worthy of note. Thus one may see in the shop windows scores of things, such as door-plates, oil-cans, settings for spirit levels, and the like, made of solid nickel. It is now generally recognised that nickel-plating is not durable, and, as the price of the metal declines, we shall doubtless see a large increase in its consumption for such purposes as those named."

*Ibid.*, Vol. III, 1894.—"The most important use of nickel so far continues to be as an alloy in the manufacture of steel. The tests made of nickel-steel for armour plates and other purposes during the past year have confirmed the evidence of previous trials as to the quality of the alloy. In other directions its use has not materially extended, although the demand for it continues to increase slightly. The market cannot be largely extended, however, unless new applications are found for the metal.

"While, as noted above, nickel steel has proved itself probably the best material for armour-plate yet tested, the experiments made with this steel, in the manufacture of heavy guns, have not yet been concluded, so that no decision has been reached as to its adaptability for the purpose. Some experiments have also been begun with nickel-steel guns in France, but there, as in the United States, no conclusion has been reached. With regard to other uses it may be noted that nickel is employed to a considerable extent in Europe for the manufacture of small articles which are, in this country, usually nickel-plated only, if the metal is used at all. With the decreasing price it is evident that there are many manufactures of this kind in which the solid metal might be almost as cheap as the plating on less expensive alloys. In France a copper-nickel alloy is used for some purposes, and is said to possess many excellent qualities. Probably other uses might be suggested where the well-known properties of this metal would make it serviceable."

*Ibid.*, Vol. V., 1896.—"The uses for nickel have not yet been so extensive as a few years ago it was predicted they would be, and up to the present time the consumption in steel-making has not been very large. The market in 1896 was, therefore, very quiet; but, although the demand was light, prices were maintained at about the same level as in 1895. At the end of the year the quotation was 33 @ 36 cents. per ℔. for ton lots."

*Ibid.*, Vol. VI., 1897.—"Nickel steel has also been the subject of experiments by the British Admiralty, and the results of its tests have been favourable to its more extensive use. It is being largely used in the new Japanese warships building in England, not only as armour-plate, but also for the cranks, propeller shafts, connecting rods, and other forgings. It is the general opinion of engineers acquainted with the qualities of this material that if it should be adopted for cylindrical boilers that have very thick shells, such as are used in large steam vessels, an important saving in weight, perhaps 25 per cent. could be effected. For railway purposes, too, this alloy must have a bright future, as it should be specially adapted for locomotive details."

*Deposits of Cobalt and Nickel Ores.*—The most important deposits of cobaltiferous and nickeliferous ores hitherto found in the Colony are situated near Carcoar, at Bungonia, and at Port Macquarie respectively. The Carcoar deposit was examined, in 1888, shortly after its discovery, by Mr. T. W. E. David, Geological Surveyor, and the following extracts are taken from his report :—

"The spot where the cobalt ore was first discovered is situated on top of a hill, three quarters of a mile south-easterly from the Carcoar railway station. The discovery was made accidentally by a miner when trenching to intersect the continuation of a neighbouring copper reef. The formation here consists of a greenish-black crystalline rock, which may be provisionally termed diorite though, probably, when it has been further examined in transparent microscopic sections, it will be found more nearly allied to the hypersthene gabbros or to teschenite. On the south-east of this mass of diorite comes a belt of greenish chloritic slate, then the cobalt vein, consisting of a succession of bunches of nearly pure cobaltiferous mispickel; then, further to the south-east, brownish-gray clay slate, with a dyke of whitish-gray felsite, outwardly resembling opaque quartz; then a considerable mass of clay-slate similar to that on the north-west side of the felsite dyke."

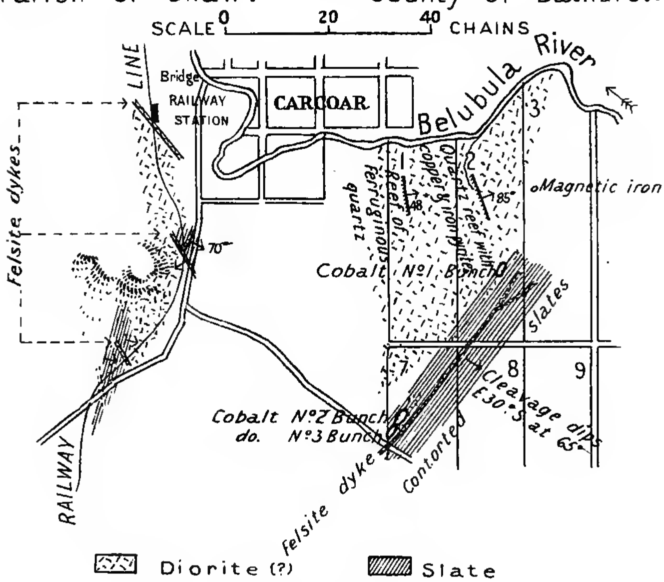
"The sections seen in the railway cuttings show clearly the relations to one another of the diorite, slate, and felsite."

"The slate is the oldest formation which has been intruded by the boss of diorite, and, subsequently, both slate and diorite have been intersected by dykes of whitish-grey felsite. The cleavage of the slates dips in direction from 10° to 30° E. of S. The diorite meets the slate near the cobalt reef in Portions 1 and 2, Parish of Shaw, along a line nearly parallel with the cobalt reef, and is traversed by a few quartz reefs, one of which contains copper pyrites and iron pyrites, and has been worked for copper, and another of which is said to contain a little gold. These reefs strike towards the cobalt reef at an oblique angle. The diorite boss, close to its junction with the slate, throws off a narrow dyke which penetrates the slate and runs parallel for some distance with the contact line of the two formations. The bunches of cobalt ore occur partly in this dyke and partly in the slate at its sides at the north-east end of the reef, while towards its south-west end the bunches are entirely in the slate The felsite dykes are from a few feet to 18 feet wide, and strike

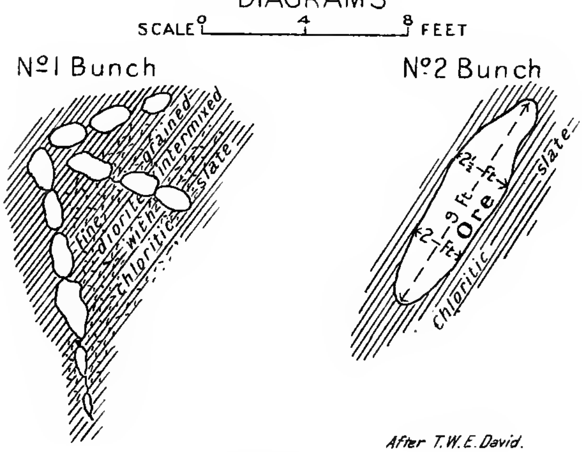
## PLAN shewing the occurrence of Cobalt Ore NEAR

# CARCOAR

Parish of Shaw. County of Bathurst.




## DIAGRAMS




*After T.W.E. David.*

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*Photo-lithographed by W. A. Gullick, Government Printer, Sydney, N.S.W.*

in various directions, but chiefly in a north-east and north-west direction. The most important of these dykes is the one which runs parallel to the cobalt reef on the south-east side of it at a distance of 40 yards. This dyke is about 18 feet wide."

"The vein, as far as at present proved, consists of a succession of lens-shaped bunches, of which three had been discovered up to the time of my inspection. These three bunches lie in the same straight line, and their longest axes also lie parallel to the same line which is itself almost exactly parallel with the junction line of the slate with the diorite, and with the strike of the large felsite dyke to the south-east of the vein.'

"The first bunch consisted of strings of small bunches ranged along three lines, which met at the point shown in the sketch plan. This bunch commenced close to the surface at its north-east end, and dipped slightly to the south-west at the rate of about 1 in 6. The whole bunch was worked out at a depth of about five feet from the surface, below which level scarcely the least trace of it remained. The smaller individual bunches consisted of irregular shaped, more or less spherical, masses of cobaltiferous mispickel and molybdenite, which merge gradually into the country rock. Some of these masses weighed over 1 cwt., and in all about five tons of ore were won from this bunch. The second bunch is a single mass, nine feet long, two and a half feet wide at the centre, and tapering off rapidly at both ends where it ceases suddenly in the chlorite slate. The ore here is massive cobaltiferous mispickel, which as in the first bunch, merges gradually into the country rock. The downward vertical extent of this bunch had not been proved at the time of my visit. The second bunch bears S. 35° W. from the first, and is thirty-five chains distant. Bearing S. 35° W. from the second bunch is the third bunch, also enclosed in chlorite slate. Its width is at least one foot, but its length had not been proved. Three bunches have, therefore, been discovered, the last being nearly half a mile distant from the first."

"Owing to the ore in the bunches being of about the same degree of hardness as the enclosing rock, they do not make any visible outcrop at the surface, such as a quartz reef does, and a great deal of trenching will consequently be necessary in order to discover the intermediate bunches which, no doubt, exist."

"*Ore.*—The ore in these bunches consists of glaucodot (a variety of cobaltiferous mispickel), erythrine (cobalt bloom), molybdenite, and thin films of an apple-green to dark-green mineral, which has been determined by Mr. J. C. H. Mingaye, F.C.S., Government Assayer and Analyst, to be annabergite (arseniate of nickel). Scarcely any molybenite was met with in No. 2 and No. 3 bunches, which were almost wholly composed of massive granular-crystalline glaudocot, with small isolated crystals of the same mineral intermixed with the chlorite, hornblende, and felspar of the gangue."

"*Glaucodot.*—The following are two analyses of this mineral made by Mr. Mingaye:—

| | Sample from No. 1 Bunch. | Sample from No. 2 Bunch. |
|---|---|---|
| Moisture ... ... ... ... ... | ·120 | 2·180 |
| Metallic arsenic ... ... ... ... | 51·810 | 29·010 |
| ,, cobalt ... ... ... ... | 10·447 | 13·830 |
| ,, nickel ... ... ... ... | ·590 | ·390 |
| ,, iron ... ... ... ... | 11·860 | 15·780 |
| ,, manganese ... ... ... | nil | nil |
| ,, calciun ... ... ... | ,, | ·710 |
| ,, magnesium ... ... ... | 1·480 | ·220 |
| Alumina ... ... ... ... ... | nil | trace |
| Gold ... ... ... ... ... | trace | ,, |
| Silver ... ... ... ... ... | ,, | nil |
| Sulphur ... ... ... ... ... | 1·520 | 11·240 |
| Gangue ... ... ... ... ... | 22·078 | 26·310 |
| | 99·905 | 99·670 |

"These analyses, as well as the crystalline form and perfect basal cleavage of the mineral, prove it to be glaucodot. The actual amount of cobalt oxide in the ore was, in No. 1 sample about 14·69, and in No. 2 sample, 19·45 per cent. In the former case over 22 cent. of gangue was present, and in the latter 26 per cent. The total amount of cobalt oxide in this mineral, the pure glaucodot, when quite freed from the gangue, would be, in the first case, nearly 19 per cent., and in the second case over 26 per cent. The annabergite (nickel bloom) is not found in sufficient quantity to be of any commercial importance."

"*Summary.*—This deposit of cobalt appears to me to have been formed in a line of fissure, which, for some distance, followed the line of junction of the diorite with the slate, and was probably directly due to the intrusion of the diorite, being formed either by the thrust of its upheaval or by the contraction consequent upon the cooling of the mass of igneous rock. Towards its north-east end this fissure was partly filled by a dyke of fine-grained diorite, closely resembling the chlorite slate, which it has penetrated. The cobalt ore was then concentrated into the irregular hollows along this line of fissure by some process of segregation, for its intimate admixture with the dyke rock is difficult of explanation on any other hypothesis, and in the case of No. 2 and No. 3 bunches by a similar process, accompanied apparently by a slight transportation of the mineral in solution into the hollows now occupied by the bunches, as in these two last cases the gradual merging of the mineral into the country rock is less apparent than in the first. The bunches will probably dip in a south-easterly direction, conforming to the dip of the cleavage of the slate rock. Notwithstanding the bunchy nature of this deposit, the richness and size of the bunches will fully justify the outlay of some capital upon its future development. The ore is exceptionally rich in cobalt, at least four times as rich as the cobaltiferous manganese ores hitherto worked for cobalt in New South Wales, and, when picked, some of it would be worth at least £20 per ton."

The following are the details of the ore shipped from this deposit by the Carcoar Cobalt Company :—

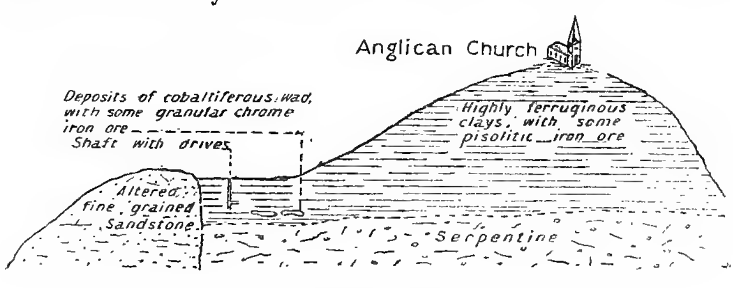
| Date. | Number of Bags (22-25 Bags to the Ton). | Value. |
|---|---|---|
| | | £ |
| November, 1891 ... ... ... | 386 | 500 |
| December, 1891 ... ... ... | 386 | 200 |
| ,, ,, ... ... ... | 345 | 500 |
| January, 1892 ... ... ... | 264 | 250 |
| ,, ,, ... ... ... | 135 | 250 |
| February, 1892 ... ... ... | 249 | 500 |
| ,, ,, ... ... ... | 118 | 200 |
| May, 1892 ... ... .. | 475 | 500 |
| February, 1893 ... ... ... | 467 | 300 |
| July, 1893 ... ... ... | 575 | 500 |
| September, 1893... ... ... | 175 | 100 |
| March, 1895 ... ... ... | 24 | 30 |
| | 3,599 | £3,830 |

The assay value of the ore varied from 5 to 15 per cent. of cobalt protoxide, the average being 9·19 per cent. The price obtained for the ore varied from £15 to £45 per ton.

*Port Macquarie Deposits.*

These deposits were examined in 1897 by Mr. J. B. Jaquet, Geological Surveyor, from whose report the following extracts are taken :—

"Cobalt appears to have been first found at Port Macquarie about eleven years ago, by Mr. E. H. Becke. It was first of all worked upon the cliffs fronting the ocean, a short distance south of Nobby's Point. What are probably the most promising deposits have been only recently discovered by Messrs. Tellefson and Wyborn. The site of these workings is in the town of Port Macquarie, about 250 yards from the Anglican Church in a southerly direction."




IDEAL SECTION, SHOWING MODE OF OCCURRENCE OF COBALT ORE AT PORT MACQUARIE.

(After J. B. Jaquet).

"The sketch above represents an ideal geological section through Church Hill, and shows the position of the ore bodies. The formations consist of considerably altered fine-grained sandstones and serpentine. I only made a cursory examination of the geological formations in the district, and my investigations are not sufficient to enable me to pronounce any definite opinion as to the probable origin of the serpentine. It appears, however, to have resulted from the alteration of a rock which at one time intruded the sandstone."

"It is only in the serpentine, and the clays which have resulted from its degradation, that the cobalt is found. The ore occurs in nests or pockets which possess no defined form, and which are scattered in an irregular manner through the clays and decomposed serpentine. It is also found upon the cleavage planes and in the joints of the rock. The most promising ore-bodies have been discovered at the base of the red ferruginous clays, and in the upper layer of serpentine which is decomposing *in situ*."

"Messrs. Tellefson and Wyborn have sunk a shaft to a depth of 20 feet, and from the bottom of the shaft they have driven several short levels into the decomposed rock, in all of which more or less cobalt ore can be seen. At the time of my inspection an inclined tunnel was being driven with a view of exploiting the deposits already discovered."

"The ore consists of earthy cobaltiferous wad (asbolite), an ore which, according to Dana, sometimes contains as much as 32 per cent. of metallic cobalt. It possesses a black or bluish-black colour. Generally speaking, the bluer the ore the greater the quantity of cobalt which it contains. This characteristic has been used in classification. Being more or less spongy in texture, it includes within its cavities small quantities of red ferruginous clayey matter. Some specimens are rudely laminated, and others possess a botryoidal or reniform structure. The whole appearance of the ore would seem to suggest that it has had a concretionary origin."

"An average sample taken by the writer from a few tons of picked ore, raised from a new find by Messrs. Wyborn and Tellefson, was analysed by Mr. J. C. H. Mingaye, Analyst to the Mines Department, with the following result :—

| | |
|---|---|
| Moisture at 100° C. ... ... ... ... ... ... | 4·98 |
| Combined water ... ... ... ... ... ... | 12·21 |
| Silica ($SiO_2$) ... ... ... ... ... ... ... | 8·06 |
| Alumina ($Al_2O_3$) ... ... ... ... ... ... | 18·95 |
| Ferric oxide ($Fe_2O_3$) ... ... ... ... ... ... | 14·78 |
| Manganese binoxide ($MnO_2$)... ... ... ... ... | 31·05 |
| Cobalt oxide (CoO) ... ... ... ... ... ... | 7·48 |
| Nickel oxide (NiO) ... ... ... ... ... ... | 1·36 |
| Chromium sesquioxide ($Cr_2O_3$) ... ... ... ... | ·41 |
| Copper oxide (CuO) ... ... ... ... ... ... | ·05 |
| Lime (CaO) ... ... ... ... ... ... ... | ·05 |
| Magnesia (MgO) ... ... ... ... ... ... | trace |
| Phosphoric acid ($P_2O_5$) ... ... ... ... ... | ·06 |
| | 99·44 |

"A picked sample of the ore from the abandoned workings on the cliff south of Nobby's Head yielded, on being analysed by Mr. H. P. White, Assistant Analyst to the Mines Department, as follows :—

| | |
|---|---|
| Moisture at 100° C. ... ... ... ... ... ... | 5·38 |
| Combined water ... ... ... ... ... ... | 12·24 |
| Silica ($SiO_2$) ... ... ... ... ... ... ... | 6·40 |
| Alumina ($Al_2O_3$) ... ... ... ... ... ... | 9·97 |
| Ferric oxide ($Fe_2O_3$) ... ... ... ... ... ... | 16·85 |
| Manganese binoxide ($MnO_2$)... ... ... ... ... | 36·50 |
| Cobalt oxide (CoO) ... ... ... ... ... ... | 7·03 |
| Nickel oxide (NiO) ... ... ... ... ... ... | 2·39 |
| Chromium sesquioxide ($Cr_2O_3$) ... ... ... ... | ·40 |
| Copper oxide (CuO) ... ... ... ... ... ... | ·12 |
| Lime (CaO) ... ... ... ... ... ... ... | 1·20 |
| Magnesia (MgO) ... ... ... ... ... ... | ·83 |
| Phosphoric acid ($P_2O_5$) ... ... ... ... ... | ·14 |
| Carbonic acid ($CO_2$) ... ... ... ... ... ... | ·22 |
| | 99·67 |

"A chrome iron ore, composed of small grains of chromite loosely cemented together, is associated with the wad in places. A sample of this ore yielded by assay :—

| | |
|---|---|
| Chromic oxide ... ... ... ... ... | 48·24 per cent. |
| Cobalt ... ... ... ... ... ... | 1·29 ,, |

'It has not been found in sufficient quantity hitherto to permit of its being worked as a chrome ore. There are also found, in the red clays, masses of pisolitic ironstone, which, upon analysis, have been found to contain small quantities of cobalt."

"The deposits which possess the greatest interest for the Port Macquarie cobalt miners, and those from which the greatest amount of information having a practical bearing upon the subject can be obtained, are found in New Caledonia. Both as regards the character of the ore and its mode of occurrence, there is a close resemblance between the two series of deposits. It is important to note that the New Caledonian ore is only found in the clays and decomposed rocks, and never in the unaltered serpentine. There are exported from New Caledonia from 2,500 to 4,000 tons of cobalt ore every year, which contains about 5 per cent. of metallic cobalt. Formerly the ore was only hand-picked before being bagged for export, but I have reason to believe that a considerable portion is now delivered of its associated red clay by a rude process of washing. The friable powdery character of the wad (and its consequent liability to slime) must always render its concentration by the ordinary processes difficult. Unfortunately, the efforts which I have made to obtain particulars of the system in vogue in New Caledonia have not been successful."

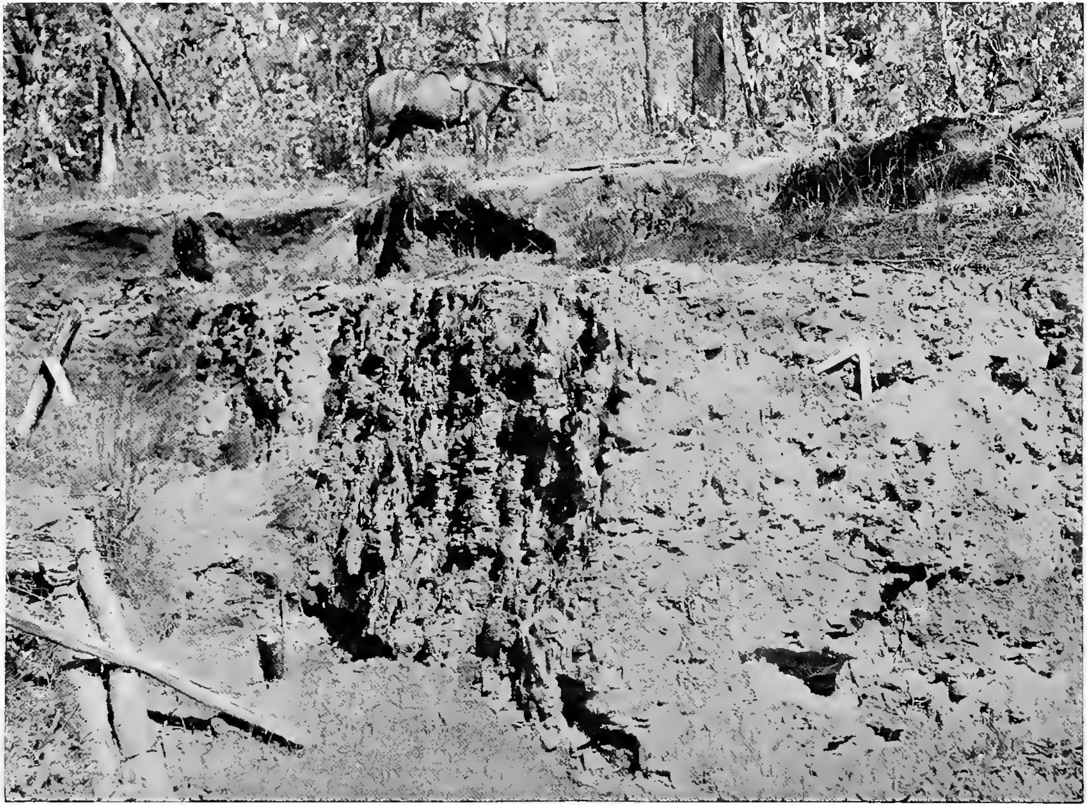
"*Treatment of the Ore.*—The Port Macquarie deposits are handy to water carriage, and the ore could be cheaply shipped. Nevertheless the ore is, comparatively speaking, light and bulky, and would not be sought after by shippers for stiffening purposes, as is the case with chrome-iron and other heavy ores."

"The late Mr. Cosmo Newbery suggested, in 1884, that the cobalt-bearing wads of Victoria might possibly be treated at a profit in the Colony by a wet process which he outlines, and which he describes as one by which very poor ores may be treated at a profit. The process would seem to be closely analogous to that in vogue at the Maletra Works, Rouen, France. Here the powdered ore is first treated, in large vats, with a solution of protosulphate of iron, and as a result, the manganese, cobalt, and nickel go into solution in the form of sulphates. The solution of sulphates is run into stone basins, and sodium sulphide is added in sufficient quantity to precipitate the nickel and cobalt as sulphides. A small quantity of manganese is also precipitated during this operation, but the greater portion of it remains in solution. The precipitate so obtained is washed, passed through a filter press, and then treated with perchloride of iron. As a result of this operation, the manganese goes into solution partly as sulphate and partly as chloride, while a, comparatively speaking, pure residue of nickel and cobalt sulphides remains behind. About 180 tons of ore per month, containing 3 per cent. cobalt (?) and $1\frac{1}{4}$ per cent. nickel, are treated at the Maletra Works."

"*Price obtained for the Ore.*—The prospectors (at Port Macquarie) have been offered £5 10s. per ton for ore containing 5 per cent. of cobalt oxide, delivered in Sydney. It would appear ("Mineral Industry," 1896, p. 247) that the value of a ton of cobalt oxide in the United States in 1896 was about £420, so the value per unit would be £4 4s., say £4. Upon this basis of calculation, the actual value of the cobalt oxide contained in a ton of 5 per cent. ore would be £20."

"It may seem somewhat extraordinary, having regard to the high intrinsic value, that buyers should refuse to quote prices for parcels containing less than 5 per cent. There is however, only a limited demand for cobalt oxide—only about 200 tons are absorbed in the arts annually; and, upon inquiry, I have learnt that a sufficient quantity of asbolite ores, yielding 5 per cent. of oxide, can readily be obtained to meet the shortage in the World's supply from other sources. I have reason to believe that the market price of the manufactured product is controlled by a small ring of merchants."

"*General Remarks.*—In my opinion the cobalt deposits of Port Macquarie and the surrounding district are well worthy of further attention on the part of the mining community. Prospecting operations have shown that bunches of payable ore exist, which is certainly as rich as, if not richer than, that which at present is being profitably mined in New Caledonia. Exploratory work has not yet proceeded far enough to enable one to express any opinion as to the dimensions of the deposits, or the quantity of ore which they are likely to yield. I am of opinion



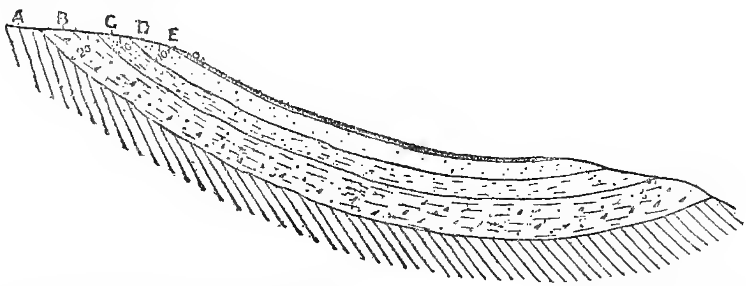
*Photographed by E. F. Pittman.*

Stratified Deposits (Tertiary) of Cobaltiferous Manganese Ore, near Bungonia.

that the chances are greatly against the ore being obtained in payable quantities at a depth in the unaltered rock ; and I would advise prospectors to confine their attention to the clays, &c., and the upper decomposed portions of the serpentine. Fresh deposits of ore are likely to be found from time to time in the district, and I would particularly direct the attention of prospectors to the outcrop of serpentine, for the most part covered by red clays and ironstones pebbles, which crosses the Taree-Port Macquarie road about twelve miles from the latter town. All the facts seem to me to suggest that the cobaltiferous wad has segregated out from the serpentine, which originally contained cobalt and nickel in a finely-disseminated state, and that the process of segregation has been assisted by the decomposition of the serpentine."

*The Bungonia Deposits.*—Deposits of cobaltiferous manganese oxide occur in several localities in the Bungonia district. They appear to be of lacustrine origin and of Tertiary age, and they rest unconformably upon Devonian claystones and quartzites.

One of these deposits, situated about three miles east of Bungonia, was worked some years ago, and a plant for treating the ore was erected on the ground, but the enterprise was eventually abandoned owing to the proportion of cobalt in the mineral being rather too low to yield a margin of profit.




A Devonian jasperoid claystones and quartzites. B Ferruginous sandstone containing subangular boulders of jasperoid claystone, &c. C Limonite with impressions of tertiary leaves. D Quartz-grit, cemented with cobaltiferous wad. E Surface soil.

SECTION OF COBALTIFEROUS DEPOSIT, NEAR BUNGONIA.

The cobaltiferous manganese oxide occurs filling the interstices of a coarse quartz-grit, and appears to have been deposited from solutions which percolated this porous rock. Concretionary nodules of the ore are not uncommon, and these are the richest portions of the deposit. An average sample was analysed in the Laboratory of the Department of Mines, and yielded at the rate of 1·53 per cent. of cobalt and 20·86 per cent. of manganese binoxide.

Immediately below the manganiferous grit is a bed of limonite, in which well preserved impressions of leaves (*Nephelites*, *Persoonia*, and *Drimys*) are abundant. The basal bed of the series is a ferruginous sandstone, containing a fair number of subangular boulders or pebbles of chert and jasperoid claystones, which have evidently been derived from the underlying Devonian beds.

*Register of localities where cobalt and nickel ores have been found.*

The following is an alphabetical list of the localities from which specimens of cobalt and nickel ores have been received in the Department of Mines for assay. The date in each case represents the year in which the assay was made. The figures refer to the percentages of metallic cobalt and metallic nickel :—

*Barrier Ranges.* (1885.) Decomposed ferruginous rock with joints filled with wad, containing 1·38 per cent. of cobalt, and 3·05 per cent. of nickel.

*Bathurst, 20 miles from.* (1885.) Wad, containing ·295 per cent. of cobalt, and a trace of nickel.

*Boro, County of Murray.* (1885.) Wad, containing 1·49 per cent. of cobalt.

,, ,, (1886.) Wad, in claystone, containing ·10 per cent. of cobalt.

,, ,, (1887.) Concretionary wad, containing 5·79 per cent. of cobalt, and 1·37 per cent. of neckel.

,, ,, (1890.) Wad, containing 1·42 per cent. of cobalt.

*Bombala, 31 miles from.* (1886.) Wad, containing 2·80 per cent. of cobalt, and ·80 per cent. of nickel.

*Broken Hill (Australian Broken Hill Consols Mine).* (1898.) Cobaltite, containing 7·12 per cent. of cobalt, and 1·90 per cent. of nickel.

*Bungonia.* (1883.) Wad, containing 2·48 per cent. of cobalt.

,, (1883.) Samples of wad containing from 2·73 to 2·78 per cent. of cobalt.

*Bungonia, 13 miles south of.* (1884.) Wad, containing 1·06 per cent. of cobalt, and 1·15 per cent. of nickel.

*Bungonia, Marulan District.* (1884.) Wad in sandstone, containing 0·86 per cent. of cobalt, and 1·32 per cent. of nickel.

*Bungonia.* (1885.) Wad, containing 2·22 per cent. of cobalt, and ·39 per cent. of nickel.

,, (1886.) Wad in claystone, containing 0·15 per cent. of cobalt.

,, (1886.) Concretionary wad, containing 2·53 per cent. of cobalt.

,, (1886.) Wad, containing 2·65 per cent. of cobalt.

,, (1886.) Grit, cemented with wad, containing 1·42 per cent. of cobalt.

,, (1886.) Wad, containing ·5 per cent. of cobalt.

,, (1887.) Wad, containing 2·44 per cent. of cobalt, and ·35 per cent. of nickel.

,, (1887.) Siliceous wad, containing 2·62 per cent. of cobalt.

,, (1887.) Wad, in fine-grained sandstone, containing 2·63 per cent. of cobalt.

,, (1887.) Wad, in fine-grained sandstone, containing 2·39 per cent. of cobalt, and ·15 per cent. of nickel.

,, (1887.) Concretionary wad with quartz, containing 2·04 per cent. of cobalt, and 1·42 per cent. of nickel.

,, (1888.) Crushed wad, containing 2·29 per cent. of cobalt, and ·31 per cent. of nickel.

,, (1888.) Crushed wad, containing 1·85 per cent. of cobalt, and ·27 per cent. of nickel.

,, (1888.) Crushed wad, containing 1·52 per cent. of cobalt, and ·31 per cent. of nickel.

,, (1889.) Wad, containing 1·88 per cent. of cobalt.

*Bungonia.* (1889.) Sandstone with wad, containing 1·36 per cent. of cobalt, and ·27 per cent. of nickel.

,, (1889.) Sandstone with wad, containing 1·33 per cent. of cobalt, and ·19 per cent. of nickel.

,, (1898.) Gritty quartz with much wad, containing 1·50 per cent. of cobalt.

*Burnt Yards.* (1898.) Cobaltiferous mispickel in a felspathic rock, containing a trace of cobalt.

*Burnt Yards.* (1899.) Siliceous and cobaltiferous mispickel containing 1·616 per cent. of cobalt, 1 oz. 12 dwt. 16 grs. of gold per ton, and 2 dwt. 4 grs. of silver per ton.

*Burnt Yard Creek.* (1897.) Iron and arsenical pyrites, containing 1·75 per cent. of cobalt.

*Burragorang.* (1890.) Earthy wad containing 2·05 per cent. of cobalt, and ·19 per cent. of nickel.

*Burragorang.* (*Tin-kettle Creek,* 1899.) Wad containing 2·26 of cobalt, and ·13 per cent. of nickel.

*Capertee,* 10 *miles from, on the Mudgee road.* (1885.) Wad in ironstone grit, containing 1·18 per cent. of cobalt, and ·35 per cent. of nickel.

*Carcoar.* (1888.) Two samples of danaite, with a little erythrine and hornblende, containing 10·44 and 13·83 per cent. of cobalt, and ·39 and ·59 per cent. of nickel respectively.

*Carcoar.* (1888.) Molybdenite, with a little felspathic material, and spots of erythrine, containing 3·01 per cent. of cobalt.

*Carcoar.* (1888.) Nickel bloom. Percentage of nickel not determined.

*Carcoar.* (1889.) Finely crystalline glaucodot and molybdenite, containing 8·23 per cent. of cobalt, and ·80 per cent. of nickel.

*Carcoar, near.* (1889.) Wad, containing 1·75 per cent. of cobalt, and ·67 per cent. of nickel.

*Carcoar.* (1890.) Quartz with arsenide and arseniate of cobalt, containing 1·36 per cent. of cobalt.

*Carcoar.* (1898.) Copper gossan, with some iron and copper pyrites, and much country rock, from Creer's copper lode, containing 2·04 per cent. of cobalt.

*Cobar District.* [*See* Mount Boppy.]

*Cookamidgera Station.* (1898.) Cobaltiferous wad from four miles south of Cookamidgera Station, containing 2·63 per cent. of cobalt.

*Fernbank, Shoalhaven River.* (1897.) Ferruginous quartz with wad, containing 1·31 per cent. of cobalt.

*Forbes.* (1899.) Cobaltiferous wad from the Union Lead, containing 2·66 per cent. of cobalt, and ·2 per cent. of nickel.

*Glen Morrison.* (1886.) Wad containing 2·54 per cent. of cobalt.

*Goulburn,* 4 *miles from.* (1885.) Wad in sandstone containing ·86 per cent. of cobalt, and 1·32 per cent. of nickel.

*Gulgong, near.* (1885.) Wad, containing ·44 per cent. of cobalt.

*Hill Top.* [*See* Mittagong.]

*Inverell District.* (1882.) Cement, containing 51·2 per cent. of tin, and ·35 per cent. of cobalt.

*Junction Reefs, Belubula River.* (1890.) Arsenical pyrites containing cobalt, in felspathic gangue showing traces of erythrine, containing 1·506 per cent. of cobalt, and a trace of nickel.

*Lake George.* (1886.) Concretionary wad containing 3·58 per cent. of cobalt.

*Lismore.* (1886.) Wad from joints in decomposed felsite, containing 1·74 per cent. of cobalt, and ·20 per cent. of nickel.

*Marulan District.* [*See* Bungonia.]

*Mittagong* (*Hill Top*). (1890.) Wad, containing 1·30 per cent. of cobalt, and ·21 per cent. of nickel.

*Mittagong* (*Hill Top*). (1899.) Wad, containing 2·29 per cent. of cobalt.

*Mount Boppy, Cobar District.* (1897.) Siliceous wad, containing 2·23 per cent. of cobalt.
*Mudgee.* (1886.) Wad, containing ·35 per cent. of cobalt.
*Nadgigomar.* (1893.) Siliceous wad containing 1·92 per cent. of cobalt, and ·40 per cent. of nickel.
,, (1898.) Cobaltiferous wad with quartz, from Conner's Creek, Nadgigomar, containing less than ·25 per cent. of cobalt.
*Nerriga, near.* (1895.) Massive arsenical pyrites, containing 9·15 per cent. of cobalt, and ·66 per cent. of nickel.
*Port Macquarie.* (1886.) Wad, containing from 2·28 to 4 per cent. of cobalt.
,, (1889.) Felspathic wad containing 2·17 per cent. of cobalt, and ·55 per cent. of nickel.
,, (1889.) Wad, containing 4·92 per cent. of cobalt and ·84 per cent. of nickel.
,, (1890.) Wad, containing 3·08 per cent. of cobalt and ·88 per cent. of nickel.
,, (1898.) Wad, containing 6·76 per cent. of cobalt.
,, (1898.) Concentrated wad, containing 4·27 per cent. of cobalt and a trace of nickel.
*Sutton Forest.* (1886.) Wad, containing ·75 per cent. of cobalt.
*Tamworth.* (1882.) Stone, containing ·28 per cent. of cobalt.
*Tamworth, near.* (1889.) Serpentinous schist with wad, containing 3·69 per cent. of cobalt, and 2·91 per cent. of nickel.
,, (1889.) Serpentinous schist with wad, containing a trace of cobalt, and 1·49 per cent. of nickel.
*Taree.* (1891.) Wad, containing 1·71 per cent, of cobalt, and ·93 per cent. of nickel.
*Temora.* (1897.) Siliceous wad, containing ·53 per cent. of cobalt.
*Trial Bay, near.* (1886.) Wad, containing 2·06 per cent. of cobalt.
*Wattle Flat.* (1898.) Wad, containing a trace of cobalt.
*Windellama, near.* (1883.) Wad in sandstone, containing 1·49 to 1·78 per cent. of cobalt.
*Woodstock, 1 mile north of.* (1893.) Wad, containing less than ·5 per cent. of cobalt.

## Production of Cobalt Ore.

| Year. | Quantity. | Value. |
|---|---|---|
| | tons. | £ |
| 1891 ... ... ... ... | 1·15 | 470 |
| 1892 ... ... ... ... | 76·00 | 1,110 |
| 1893 ... ... ... ... | 26·00 | 305 |
| 1894 ... ... ... ... | 2·50 | 10 |
| 1895 ... ... ... ... | 5·50 | 26 |
| 1896 ... ... ... ... | ........... | ............ |
| 1897 ... ... ... ... | ........... | ............* |
| 1898 ... ... ... ... | 116·85 | 560 |
| 1899 ... ... ... ... | 189·95 | 899 |
| Totals ... .. | 417·95 | 3,380 |

* Ten tons of cobalt, nickel, and manganese ore were raised at Kempsey during 1897; valued at £200.

# MANGANESE.

Ores of manganese occur in considerable quantities as well as in widely separated localities in New South Wales; but owing to the low price obtainable, viz., from £2 to £2 10s. per ton in Sydney, for ore containing not less than 50 per cent. of the metal, or 79·09 per cent. of $MnO_2$, mining operations have not been carried on to any great extent. Most of the known deposits are situated at a considerable distance from the seaboard, and hence the cost of transport, when added to that of winning the ore, does not allow a sufficient margin of profit in many instances.

Deposits of manganese ores are found in this Colony in Palæozoic and Mesozoic sediments, as well as in Recent or Pleistocene clays; they also occur associated with intrusive hornblendic rocks and serpentines. The following is a list of the principal manganese minerals which have been recognised:—

*Pyrolusite.*—Manganese dioxide; $MnO_2$. Commonly columnar, often divergent; also granular, massive, and frequently in reniform coats; soft, often soiling the fingers; hardness, 2—2·5; specific gravity, 4·82; colour, iron-black, dark steel-gray, sometimes bluish; streak, black or bluish-black; sometimes submetallic; opaque. Is one of the commcnest ores of manganese, and is found in many localities.

*Psilomelane or Wad.*—Hydrous manganese manganate; $H_4MnO_5$. Massive and botryoidal; reniform, stalactitic; hardness 5—6; specific gravity, 3·7—4·7; lustre, submetallic, dull; streak, brownish-black, shining; colour, iron-black, passing into dark steel-gray; opaque. This is also an ore of common occurrence (*vide* list of localities).

*Manganite.*—Hydrous manganese sesquioxide; $Mn_2O_3H_2O$. Occurs in orthorhombic crystals, often grouped in bundles; also columnar; seldom granular; stalactitic; brittle; hardness, 4; specific gravity, 4·2—4·4; lustre, submetallic; colour, dark steel-gray to iron-black; streak, reddish-brown, sometimes nearly black; opaque. Occurs at Back Creek, near Rockley.

*Diallogite.*—Carbonate of manganese; $MnCO_3$. Usually massive to granular-massive and compact; also globular and botryoidal, with columnar structure, sometimes indistinct; brittle; hardness, 3·5—4·5 specific gravity, 3·45—3·6; lustre, vitreous, inclining to pearly; colour, rose red, yellowish-grey, fawn, dark red, brown; streak, white; translucent. Said to occur (Liversidge, "Minerals of New South Wales") at Back Creek, near Rockley.

*Rhodonite.*—Silicate of manganese; $MnO\ SiO_2$. Occurs in triclinic crystals; commonly massive; cleavable to compact; also in embedded grains; very tough when compact. Hardness, 5·5—6·5; specific gravity, 3·4—3·68; lustre vitreous; colour light-reddish, brown, flesh-red, rose-pink; streak, white; transparent to translucent. Occurs as crystals in the gangue of the Broken Hill Silver Lode, associated with garnets; found in a massive condition at a number of other localities, such as Back Creek, near Rockley, Glanmire, Bendemeer, Armidale, etc.

*Braunite.*—3 $Mn_2O_3\ Mn\ SiO_3$. Occurs in octahedrons; also massive. Fracture uneven to sub-conchoidal; brittle; hardness, 6—6·5; specific gravity, 4·75—4·82; lustre, submetallic; colour, dark brownish-black to steel-gray; streak the same. Found, according to Professor Liversidge ("Minerals of New South Wales"), at Rylstone, Port Macquarie, Bungendore, Caloola, Gundagai, and in the Wellington District.

*Uses of Manganese.*—The following information in regard to the uses of manganese is taken from "The Mineral Industry":—"Over nine-tenths of the manganese production of the world is used in the manufacture of the alloys of iron and manganese, known as ferro-manganese and spiegeleisen, which are largely used in steel-making. The rest of the manganese production is used in making rarer alloys; as a reagent in the manufacture of chlorine and bromine; to decolourise, as well as to colour, glass; as a drier in varnishes; as one of the elements in Leclanché's battery; in the preparation of oxygen on a small scale; in the manufacture of disinfectants (manganates and permanganates); in calico printing, and in dyeing; in colouring pottery and bricks, and in making paints; as well as numerous other minor industries."

The following extracts in regard to the use of manganese in steel-making are from Turner's "Metallurgy of Iron and Steel":—

"A century had passed since Huntsman introduced cast-steel, and no improvement of importance had taken place in this branch of manufacture, when in 1840 the use of manganese was adopted by the Sheffield steel-makers, it having been patented by J. M. Heath for this purpose in the previous year. He discovered that the addition of manganese during the melting of crucible steel greatly improved its welding properties, while by allowing of the use of British iron it reduced the cost of manufacture by about 50 per cent., and at the same time rendered this country in a great measure independent of those supplies of Russian and Swedish iron upon which it had previously relied for the production of steel of the first quality. . . . . .

"In producing steel from Swedish iron (in 1856) Bessemer had two further difficulties to meet. During the "blow" in the converter the silicon and carbon were gradually eliminated until, at the conclusion of the operation, the resulting fluid metal was nearly pure iron; it was, in fact, much purer than the best varieties of wrought-iron imported from Sweden. It was thus too soft and malleable for the purpose of steel manufacture, and some method was needed whereby the required content of carbon could be obtained. At the same time the metal was often red-short, and cracked, or even crumbled to pieces when rolled at a red heat. Both of these difficulties were remedied by the addition of a suitable proportion of "spiegeleisen," a variety of cast-iron rich in manganese and carbon."

"The importance of manganese as an addition to Bessemer steel was recognised from the first by R. Mushet, who took out patents to cover all possible methods of introducing this element, his first patent being dated September 22, 1856."

"The proportion of manganese which is met with in iron produced in the blast furnaces ranges from a mere trace to upwards of 86 per cent., and, speaking generally, the higher the percentage of manganese the more valuable is the product, on account of the use of this element by the steel-maker. The physical properties of cast-iron are not greatly altered so long as the manganese present does not much exceed 1 per cent., and larger proportions may be present in siliceous iron without producing the appearance in the fracture which is so characteristic of manganese. When about 1·5 per cent. of manganese is present the iron is very appreciably harder to the tool, and is more suitable for smooth or polished surfaces. But when the amount of silicon is relatively small, and the manganese exceeds 1·5 per cent., a white iron is obtained with a glistening fracture showing flat crystalline plates, which, when very marked, leads to the application of the name of 'spiegeleisen' or mirror iron, and which is too hard to be cut by cast-steel tools 'Spiegeleisen' contains up to 20 per cent. of manganese, but with higher proportion the grain becomes once more uniformly close and granular, and a material is obtained which exhibits a characteristic light gray colour, and which is so brittle that it may be readily pounded in an iron mortar. To these varieties the term 'ferro-manganese' is applied; while for some purposes an iron rich in both silicon and manganese, containing, for example, 10 per cent. of silicon and 20 per cent. of manganese, is produced, and is known as 'silicon-spiegel' or 'silicon ferro-manganese'. . . . The good effect of manganese appears to be twofold; by its own action it leads directly to a measure of hardness and closeness of grain which is beneficial, while indirectly it is useful in preventing the absorption of sulphur during remelting."

"The subject has been carefully studied by W. J. Keep, who states that the addition of manganese to cast iron renders it less plastic, and consequently more brittle; it also increases the shrinkage during cooling, though the effect of manganese can, to a great extent, be neutralised by the addition of silicon. Mr. Keep states that in some of his experiments an increase of 1 per cent. of manganese led to an increase of hardness of about 40 per cent., and this hardness appeared to be due to the action of the manganese itself, and not to an indirect effect caused through an alteration in the amount of the combined carbon."

*Value of Manganese Ore.*—In the "Mineral Industry" for 1897, Vol. VI, it is stated that the price of manganese ore, delivered at Bessemer, Pennsylvania, is determined by the Carnegie Smelting Company according to the following schedule, which is based on ores containing less than 8 per cent. of silica and 0·10 per cent. of phosphorus :—

| Tenor in Manganese. Per cent. | Price per Unit. Fe. | Mn. |
|---|---|---|
| Over 49 ... ... ... ... | 6 cents. | 28 cents. |
| 46 to 49 ... ... ... ... | 6 ,, | 27 ,, |
| 43 to 46 ... ... ... ... | 6 ,, | 26 ,, |
| 40 to 43 ... ... ... ... | 6 ,, | 25 ,, |
| 37 to 40 ... ... ... ... | 6 ,, | 24 ,, |
| 34 to 37 ... ... ... ... | 6 ,, | 23 ,, |
| 31 to 34 ... ... ... ... | 6 ,, | 22 ,, |

For each unit of silica in excess of 8 per cent. a deduction of 15 cents per ton is made, and one cent. per unit of manganese for each 0·02 per cent. of phosphorus in excess of 0·1 per cent. Settlements are based on samples dried at 212° F.

*Register of Localities.*—The following is a complete register of the localities where manganese ores are known to occur in New South Wales, together with details of all the assays of samples of ore forwarded to the Department of Mines.

| Locality. | Date of Assay. | Description of Ore. | $MnO_2$ per cent. |
|---|---|---|---|
| Armidale ... ... ... | 1891 | Manganese oxide ... ... ... | 87·44 |
| ,, District ... ... | 1892 | ,, ,, ... ... ... | 39·95 |
| ,, ... ... ... | 1896 | ,, ,, ... ... ... | 61·29 |
| ,, ... ... ... | 1896 | ,, ,, ... ... ... | 83·40 |
| ,, 12 miles from ... | 1898 | Rhodonite ... ... ... ... | 55·91 |
| Aberbaldie (Walcha Road) ... | 1898 | Black oxide of manganese ... ... | 62·93 |
| Alicktown ... ... ... | 1892 | Pyrolusite ... ... ... ... | 68·57 |
| ,, ... ... | 1896 | Pyrolusite ... ... ... ... | 58·87 |
| Bathurst, 20 miles from ... | 1885 | Earthy wad ... ... ... ... | 65·10 |
| ,, District ... ... | 1890 | Massive oxide of manganese ... | 82·08<br>80·92 |
| ,, ,, 20 miles from Kelso. | 1890 | Manganese oxide with a little quartz | 63·75 |
| Bathurst ... ... ... | 1891 | Manganese oxide ... ... ... | 62·30 |
| ,, 10 miles from ... | 1892 | Siliceous manganese oxide with rhodonite. | 42·90 |
| Bathurst and Rockley, between | 1895 | Manganese oxide ... ... ... | 90·81 |
| ,, District ... ... | 1895 | Black oxide of manganese ... | 76·63<br>86·16 |
| Bendemeer ... ... ... | 1882 | Wad ... ... ... ... ... | 86·20 |
| ,, ... ... ... | 1884 | ,, ... ... ... ... | 89·60<br>73·00 |
| ,, ... ... ... | 1886 | Ferro-manganese oxide ... | 88·4<br>62·3 |
| ,, ... ... ... | 1886 | ,, ,, ,, ... | 44·1<br>75·0 |

| Locality. | Date of Assay. | Description of Ore | $MnO_2$ per cent. |
|---|---|---|---|
| Bendemeer ... ... ... | 1890 | Manganese oxide ... ... ... | 70·31 |
| ,, ... ... ... | 1891 | ,, ,, with ochreous iron oxide. | 61·91 |
| ,, ... ... ... | 1894 | Ferruginous oxide of manganese | 73·47<br>72·58 |
| ,, Giant's Den ... | 1894 | Manganese oxide ... ... | 85·65<br>71·23 |
| ,, ... ... ... | 1895 | ... ... ... ... ... ... | 95·82 |
| Bingara, 8 miles north of (Bobby Whitlow Creek). | 1894 | ... ... ... ... ... ... | 83·88 |
| Bingara... ... ... ... | 1898 | Black oxide of manganese ... ... | 73·47 |
| Bodangora, Wellington ... | 1897 | Black oxide of manganese with a trace of gold. | 55·36 |
| Bogan District ... ... | 1887 | Manganese oxide ... ... ... | 87·20 |
| Boro (Goulburn District) ... | 1879 | Oxide of manganese, mixed with quartz. | 23·27<br>37·84 |
| Bowning ... ... ... | 1886 | Manganese oxide ... ... ... | 91·00 |
| Brawlin ... ... ... | 1895 | ,, ,, ... ... ... | 78·63 |
| Bringelet, Parish of (near Bathurst). | 1885 | Wad ... ... ... ... | 63·90<br>60·35<br>52·50 |
| Broad Meadows, 50 miles from Glen Innes. | 1899 | Earthy-black oxide of manganese ... | 76·70 |
| Bundarra, 30 miles west of ... | 1896 | Black oxide of manganese ... ... | 86·30 |
| Burra Burra ... ... ... | 1894 | ,, ,, ... ... | 77·74 |
| Burragorang ... ... ... | 1890 | Earthy wad ... ... ... ... | 19·95 |
| Camden Haven Heads, near... | 1893 | Psilomelane ... ... ... ... | 58·03 |
| Canberra, 10 miles from Queanbeyan. | 1894 | Manganese oxide ... ... ... | 93·45 |
| Canberra, 10 miles from Queanbeyan. | 1896 | ,, ,, ... ... ... | 78·23 |
| Canowindra ... ... ... | 1895 | Psilomelane ... ... ... ... | 85·65 |
| Capel, Parish of, County of Murchison. | 1894 | Manganese oxide ... ... ... | 68·36 |
| Carcoar, near ... ... ... | 1889 | ,, ,, ... ... ... | 48·21 |
| Clifden, Cowra District ... | 1890 | Ferro-manganese oxide ... ... | 68·91 |
| Condobolin, 60 miles north-west of. | 1893 | Psilomelane ... ... ... ... | 40·96 |
| Condobolin ... ... ... | 1899 | Flinty-black oxide of manganese ... | 84·57 |
| ,, ... ... ... | 1899 | Psilomelane ... ... ... ... | 73·17 |
| Cookamidgera, near Parkes... | 1899 | Compact black oxide of manganese... | 48·70 |
| Coolac ... ... ... ... | 1893 | Wad ... ... ... ... ... | 66·05 |
| Cooma ... ... ... ... | 1888 | Manganese oxide ... ... ... | 74·10 |
| ,, District ... ... | 1893 | Ferruginous wad ... ... ... | 54·62 |
| ,, ... ... ... ... | 1895 | Siliceous manganese ore ... ... | 77·44 |
| ,, ... ... ... ... | 1898 | Black oxide of manganese ... ... | 95·47 |
| Coota, Parish of ... ... | 1894 | Manganese oxide ... ... ... | 67·09 |
| Cootamundra ... ... ... | 1891 | Oxide of manganese with fragments of micaceous slate and a little quartz. | 81·98 |
| ,, ... ... ... | 1893 | Psilomelane .. ... ... ... | 67·58 |
| ,, ... ... ... | 1894 | Manganese oxide ... ... ... | 46·29 |
| ,, ... ... ... | 1895 | Psilomelane ... ... ... ... | 73·55 |

| Locality. | Date of Assay. | Description of Ore. | Mn $O_2$ per cent. |
|---|---|---|---|
| Cootamundra ... ... ... | 1899 | Black oxide of manganese ... ... | 44·67 |
| Cooyal (Mudgee District) ... | 1890 | Oxides of iron and manganese | 38·73<br>47·21<br>35·30 |
| ,, ... ... .. ... | 1891 | Oxide of manganese ... ... ... | 60·90 |
| Cowong Range, the foot of ... | 1894 | Manganese oxide ... ... ... | 66·59 |
| ,, ,, ... ... | 1894 | Silicate of manganese on black quartz, with traces of gold and silver. | 46·93 |
| ,, ,, ... ... | 1894 | Black oxide of manganese, with traces gold and silver. | 50·80 |
| Cowra ... ... ... ... | 1891 | Oxide of manganese ... ... | 80·29<br>78·80 |
| ,, ... ... ... ... | 1895 | ,, ,, ... ... ... | 78·07 |
| Cudgegong ... ... ... | 1892 | Pyrolusite with clay ... ... ... | 74·70 |
| Dubbo ... ... ... ... | 1893 | Quartz stained with manganese oxide | 29·18 |
| ,, near ... ... ... | 1893 | Pyrolusite ... ... ... ... | 89·70 |
| Daylight Creek, Sunny Corner | 1898 | Black oxide of manganese ... ... | 70·86 |
| Euriowie, 6 miles north-east of. | 1898 | ,, ,, ,, ... ... | 95·54 |
| Fairy Meadow (Braidwood District). | 1880 | Wad ... ... ... ... ... | 70·00 |
| Fontana Reef (near Bathurst). | 1885 | ,, ... ... ... ... .. | 91·55 |
| Farkinson Siding, 4 miles from | 1895 | Oxide of manganese ... ... ... | 80·60 |
| Flyer's Creek (Burnt Yards)... | 1897 | Black oxide of manganese ... ... | 77·50 |
| ,, ,, ... ... ... | 1898 | ,, ,, ,, ... ... | 56·43 |
| Glanmire, near ... ... | 1883 | Wad ... .. ... ... ... | 53·18 |
| ,, ... ... ... | 1885 | ,, ... ... ... ... ... | 63·70 |
| ,, from 20 feet lead ... | 1885 | ,, ... .. ... ... ... | 71·97 |
| ,, ... ... ... | 1885 | Pyrolusite and rhodonite ... ... | 48·40 |
| Glanmire ... ... ... | 1899 | Black oxide of manganese ... ... | 87·23 |
| Glen Morrison, near ... ... | 1889 | Oxide of manganese with a little felspathic material. | 67·73 |
| Goulburn, 34 miles south of... | 1880 | Wad ... ... ... ... ... | 77·20 |
| ,, 20 miles east of ... | 1898 | Black oxide of manganese ... ... | 71·37 |
| ,, near ... ... | 1898 | ,, ,, ,, ... ... | 82·75 |
| ,, 20 miles south of... | 1899 | Siliceous black oxide of manganese... | 67·02 |
| Grafton... ... ... ... | 1893 | Manganese oxide containing clayey iron ore. | 57·77 |
| ,, District ... ... | 1893 | Black oxide of manganese ... | 72·82<br>64·37<br>37·06 |
| Gulgong ... ... ... | 1885 | Wad ... ... ... ... ... | 62·05 |
| ,, ... ... ... ... | 1891 | Ferruginous manganese oxide ... | 46·28 |
| Gundagai ... ... .. | 1891 | Oxide of manganese ... ... ... | 78·05 |
| ,, 7 miles east of ... | 1892 | ,, ,, ... ... ... | 79·56 |
| ,, 7 miles from ... | 1893 | Gossan with manganese oxide ... | 39·58 |
| ,, ... ... ... | 1893 | Psilomelane ... ... ... ... | 86·64 |
| ,, 15 miles west of ... | 1894 | Ferruginous oxide of manganese ... | 64·52 |
| ,, near ... ... | 1899 | Ferruginous black oxide of manganese | 33·17 |
| ,, ... ... ... | 1899 | Black oxide of manganese ... ... | 77·00 |
| Harden, 15 miles from ... | 1894 | Ferruginous oxide of manganese | 77·91<br>55·64 |

| Locality. | Date of Assay. | Description of Ore. | $MnO_2$ per cent. |
|---|---|---|---|
| Hastings River (Doyle River) | 1893 | Ferruginous pyrolusite ... .. | 54·28 |
| Havilah (Mudgee District) ... | 1892 | Manganese oxide, with a little clay and oxide of iron. | 77·94<br>48·28 |
| Hill Bank ... ... ... | 1890 | Oxide of manganese ... ... ... | 91·21 |
| Hill End ... ... ... | 1890 | ,, ,, ... ... ... | 81·40 |
| Jerrawa ... ... ... | 1898 | Black oxide of manganese ... ... | 52·34 |
| Kelso ... ... ... ... | 1898 | Siliceous manganese ore, probably rhodonite. | 63·39 |
| Kerr's Creek ... ... ... | 1893 | Ferruginous pyrolusite ... ... | 82·09 |
| ,, ,, 3 miles from railway station. | 1894 | Ferruginous clay, with trace of gold and silver. | 40·32 |
| Lyndhurst, 8 miles north of . | 1898 | Rhodonite, with magnetic iron ore.. | 24·87 |
| Mandurama (Barlow's Hill)... | 1897 | Calcareous manganese ore, probably carbonate in part. | 49·03 |
| Marulan, near... ... ... | 1899 | Sand, cemented with cobaltiferous wad. | 30·24 |
| Michelago, near Margaret Creek. | 1893 | Psilomelane ... ... ... | 66·00<br>45·10<br>58·68 |
| Mittagong (Hill Top) ... | 1890 | Wad ... ... ... ... ... | 24·05 |
| ,, ,, ... | 1899 | ,, (2·29 per cent. cobalt)... ... | 49·84 |
| Molong... ... ... ... | 1887 | Manganese ore ... ... ... | 67·35 |
| ,, ... ... ... ... | 1896 | Wad ... ... ... ... ... | 77·82 |
| Moonbi (Tamworth District)... | 1890 | Oxide of manganese ... ... ... | 77·71 |
| ,, ,, ,, ... | 1890 | Earthy oxide of manganese ... ... | 60·82 |
| ,, ,, ,, .. | 1891 | Oxide of manganese, with a little silicate. | 96·00 |
| ,, ,, ,, ... | 1891 | Oxide of manganese ... ... | 60·69<br>74·56 |
| ,, ,, ,, ... | 1893 | Psilomelane ... ... ... .. | 71·52 |
| ,, 12 miles from ... | 1894 | Oxide of manganese ... ... ... | 80·41 |
| ,, 12 ,, ... | 1894 | ,, ,, with rhodonite.. | 56·45 |
| ,, 10 ,, ... | 1897 | Black oxide of manganese ... ... | 82·25 |
| Moonebah (Macleay River)... | 1894 | ,, ,, ... ... | 62·10 |
| Mount Boppy, near Cobar ... | 1893 | Ferruginous pyrolusite ... ... | 55·18 |
| Mudgee ... ... ... | 1886 | Earthy manganese oxide ... ... | 23·60 |
| ,, 4 miles from... ... | 1890 | Oxide of manganese ... ... ... | 70·58 |
| ,, 2 ,, ... ... | 1890 | ,, ,, ... ... ... | 75·65 |
| ,, 6 miles east of ... | 1892 | Clay, with manganese oxide ... | 37·60 |
| ,, 6 ,, ... ... | 1892 | Pyrolusite, with limonite ... ... | 51·70 |
| ,, District ... ... | 1892 | ,, ,, ... ... | 80·12 |
| ,, 7 miles north-east of | 1892 | Manganese oxide with a little clay... | 57·06 |
| ,, 5 miles from ... | 1893 | Ferruginous psilomelane ... ... | 47·50 |
| ,, 6 miles from ... | 1894 | Oxide of manganese ... ... | 80·16<br>65·32 |
| ,, ... ... ... ... | 1897 | Black oxide of manganese ... ... | 65·64 |
| Murrumbateman ... ... | 1898 | Oxide of manganese, in part concretionary, in part crystalline. | 93·64 |
| Muttama, near ... ... | 1894 | Oxide of manganese ... ... ... | 70·48 |
| Nadgigomar ... ... ... | 1893 | Siliceous psilomelane... ... ... | 44·31 |
| Nambucca River (Taylor's Arm). | 1893 | Wad ... ... ... ... ... | 36·57 |
| Newbridge ... ... ... | 1886 | Earthy manganese oxide ... ... | 61·17 |

| Locality. | Date of Assay. | Description of Ore. | Mn $O_2$ per cent. |
|---|---|---|---|
| Newbridge ... ... ... | 1892 | Manganese oxide ... ... ... | 80·25 |
| ,, ... ... ... | 1899 | Black oxide of manganese ... ... | 83·43 |
| ,, 8 miles from ... | 1899 | ,, ,, ... ... | 96·66 |
| ,, 4 miles from ... | 1886 | Manganese oxide ... ... ... | 54·35 |
| Newcastle District ... ... | 1886 | Earthy compact manganese ore ... | 53·00 |
| New England ... ... ... | 1884 | Wad ... ... ... ... ... | 86·85 |
| ,, (Mitchell's Creek) | 1890 | Oxide of manganese ... ... ... | 73·46 |
| Orange, 14 miles south-west of | 1891 | ,, ,, ... ... | 85·50<br>75·59 |
| ,, near ... ... ... | 1893 | ,, ,, ... ... ... | 80·67 |
| Parkes, near ... ... ... | 1898 | Black oxide of manganese ... ... | 80·29 |
| ,, ,, ... ... ... | 1899 | ,, ,, ... | 71·21<br>64·72 |
| ,, 8 miles east of ... | 1899 | ,, ,, ... ... | 59·69 |
| Peak Hill, near ... ... | 1894 | Oxide of manganese ... ... ... | 70·48 |
| ,, 5 miles east of ... | 1897 | Pyrolusite ... ... ... ... | 75·93 |
| Queanbeyan ... ... ... | 1893 | Psilomelane ... ... ... ... | 52·67 |
| ,, 3 miles north of | 1895 | Quartz with pyrolusite ... ... | 89·21 |
| ,, ... ... ... | 1896 | Wad ... ... ... ... | 69·20<br>71·14 |
| ,, ... ... ... | 1896 | ,, ... ... ... ... ... | 75·10 |
| ,, ... ... ... | 1897 | Black oxide of manganese with ferruginous clay. | 71·18 |
| Rockley, 5 miles from ... | 1885 | Wad ... ... ... ... ... | 42·60 |
| ,, ... ... ... | 1890 | Oxide of manganese ... ... ... | 70·78 |
| ,, ... ... ... | 1891 | ,, ,, ... ... | 93·21<br>54·09<br>80·00 |
| ,, ... ... ... | 1892 | ,, ,, with rhodonite | 63·93 |
| ,, ... ... ... | 1892 | Oxide of manganese ... ... ... | 83·99 |
| ,, ... ... ... | 1893 | Psilomelane and rhodonite ... ... | 65·02 |
| ,, (Back Creek) ... | 1896 | Black oxide of manganese ... | 62·11<br>79·86 |
| ,, ,, ... | 1898 | ,, ,, ... ... | 96·34 |
| ,, ,, ... | 1898 | ,, ,, ... ... | 60·99 |
| ,, ,, ... | 1898 | ,, ,, ... ... | 71·37 |
| ,, ,, ... | 1899 | ,, ,, ... ... | 61·59 |
| Rockvale District ... ... | 1899 | Manganese ore, silicate in part ... | 50·61 |
| Sofala ... ... ... ... | 1898 | Siliceous manganese ore (rhodonite in part). | 66·21 |
| Stony Batta, near Uralla ... | 1884 | Wad ... ... ... ... ... | 85·25 |
| Sutton Forest ... ... ... | 1886 | Earthy compact manganese oxide ... | 46·64 |
| Tabulam (Clarence River) .. | 1893 | Psilomelane ... ... ... ... | 78·92 |
| Tamworth, from ranges near | 1885 | Wad ... ... ... ... ... | 17·20 |
| ,, 15 miles from ... | 1889 | Oxide of manganese, with a little silicate. | 77·35 |
| ,, ... ... ... | 1893 | Pyrolusite ... ... ... ... | 80·78 |
| ,, ... ... ... | 1896 | Oxide of manganese ... ... ... | 71·90 |
| ,, ... ... ... | 1897 | Black oxide of manganese ... ... | 75·13 |
| ,, near ... ... | 1898 | ,, ,, ... ... | 78·83 |
| Temora, near ... ... ... | 1894 | Oxide of manganese ... ... ... | 74·75 |
| Tenterfield ... ... ... | 1893 | Pyrolusite ... ... ... ... | 89·93 |

| Locality. | Date of Assay. | Description of Ore. | Mn $O_2$ per cent. |
|---|---|---|---|
| Trunkey ... ... ... | 1879 | Wad ... ... ... ... ... | 34·93 |
| Tumut district ... ... | 1893 | Manganese oxide ... ... ... | 79·88 |
| ,, near ... ... ... | 1894 | ,, ... ... ... | 58·93 |
| Uralla ... ... ... ... | 1894 | ,, ... ... ... | 82·58 |
| ,, district ... ... ... | 1899 | Concretionary black oxide of manganese. | 57·90 |
| Walcha ... ... ... ... | 1886 | Manganese oxide ... ... ... | 82·85 |
| ,, 2½ miles north of ... | 1892 | ,, ... ... | 23·49<br>43·28 |
| ,, ... ... ... ... | 1898 | Black oxide of manganese ... ... | 81·79 |
| ,, ... ... ... ... | 1898 | Siliceous black oxide of manganese... | 59·22 |
| ,, ... ... ... ... | 1898 | Black oxide of manganese ... ... | 82·44 |
| Wallang, county Roxburgh .. | 1881 | Wad ... ... ... ... ... | 18·50 |
| Wallendbeen ... ... .. | 1896 | Oxide of manganese ... ... ... | 43·55 |
| Wallerawang, 5 miles from ... | 1892 | ,, ... ... ... | 66·77 |
| Warialda ... ... ... | 1896 | Very compact manganese ore ... | 89·70 |
| Wattle Flat ... ... ... | 1898 | Black oxide of manganese .. ... | 57·77 |
| Willie Willie, Upper Macleay River. | 1895 | ,, ,, ... ... | 68·39 |
| Willyama, Parish of (Barrier Ranges). | 1898 | Silicate and oxide of manganese ... | 58·09 |
| Willyama, Parish of (Barrier Ranges). | 1898 | Black oxide of manganese ... ... | 62·76 |
| Woodstock, 1½ mile north of.. | 1892 | Manganese oxide ... ... ... | 74·40 |
| ,, ... ... ... | 1892 | Ferruginous manganese oxide ... | 72·90 |
| ,, 1 mile north of... | 1893 | Manganese ore ... ... ... | 66·92 |
| ,, 9 miles west of... | 1889 | Black oxide of manganese ... ... | 65·80 |
| Woolgoolga .. ... ... | 1893 | Psilomelane ... ... ... ... | 49·16 |
| Yass, near ... ... ... | 1881 | Wad with traces of cobalt ... ... | 78·40 |

## Production of Manganese Ore.

| Year. | Quantity. | Value. |
|---|---|---|
| | tons. | £ |
| 1884 ... ... ... ... | 200·00 | 560 |
| 1885 ... ... ... | ............ | ............ |
| 1886 ... ... ... ... | ............ | ............ |
| 1887 ... ... ... ... | ............ | ............ |
| 1888 ... ... ... ... | ............ | ............ |
| 1889 ... ... ... ... | ............ | ............ |
| 1890 ... ... ... .. | 100·00 | 325 |
| 1891 ... ... ... ... | 138·20 | 340 |
| 1892 ... ... ... ... | 15·80 | 47 |
| 1893 ... ... ... ... | ............ | ............ |
| 1894 ... ... ... ... | 13·50 | 44 |
| 1895 ... ... ... ... | 3·35 | 10 |
| 1896 .. ... ... ... | ............ | ............ |
| 1897 ... ... ... ... | ............ | ............ |
| 1898 ... ... ... ... | 1·00 | 5 |
| 1899 ... ... ... ... | ............ | ............ |
| Totals ... ... | 471·85 | 1,331 |

# ANTIMONY.

Ores of antimony are of common occurrence in New South Wales, and are distributed over widely separated areas. The principal ore is the sulphide, known as antimonite, antimony glance, or stibnite, and it occurs most generally in lodes with a quartz gangue, intersecting palæozoic sedimentary rocks, as well as granites and other igneous rocks. Frequently the most productive lodes are found in sediments near their junction with intrusive granites. In some instances the lodes are composed of massive stibnite, while in others the mineral is disseminated through a greater or less amount of useless gangue.

*Associated Minerals.*—Galena is not infrequently associated with stibnite in lodes, and in such cases the galena is often found to carry a considerable proportion of silver, as at Stony Batta, Reedy Creek, and near Walcha, in New England. The association of gold with antimony ores is a noteworthy feature of some of our productive lodes, and has given rise to some difficulty in the profitable extraction of the precious metal. The occurrence of gold in conjunction wih stibnite in lodes is a special feature of the Hillgrove field, near Armidale, and these lodes also contain scheelite, or tungstate of lime. Auriferous antimony ores are also found in the Bingara, Capertee, Carangula, Marulan, Nundle, Sofala, and other districts.

A characteristic feature of the Lucknow Mines, near Orange, is the occurrence of native antimony, and occasionally stibnite, in association with free gold, and extraordinarily rich auriferous mispickel in a calcite gangue.

In the Australian Broken Hill Consols Mine the association of antimony with silver is notable, and quite a number of antimonial silver minerals have been found. The most important of these is dyscrasite, which occasionally occurs in large masses, and which was at first mistaken for native silver.

*Ores of Antimony.*—The following are the principal ores of antimony, with a description of their chief physical characteristics.

*Native Antimony.*—Rhombohedral crystals; generally massive, lamellar, and distinctly cleavable; also radiated; sometimes botryoidal or reniform with a granular texture; very brittle. Hardness 3–3·5; specific gravity, 6·65–6·72; lustre metallic; colour and streak tin white. Occurs in calcite at the Lucknow Mines near Orange, and at Gara, twelve miles from Armidale.

*Stibnite* or *Antimonite.*—Sulphide of antimony, $Sb_2 S_3$. Contains when pure 71·4 per cent. of metallic antimony. Occurs in prismatic crystals, and commonly in confused aggregates of acicular crystals, and in radiating groups. Also frequently massive in lodes, and sometimes granular. Hardness, 2; specific gravity, 4·52–4·62; lustre metallic; colour and streak lead-gray. This is the most common ore of antimony, and it frequently shows a crust of yellowish oxide. It occurs in a great many localities—*vide* register of localities below.

*Cervantite.*—Antimony oxide, $Sb_2 O_4$. Contains 78·9 per cent. of metallic antimony. Occurs massive, also as a crust or coating on stibnite, and in acicular orthorhombic crystals. Hardness, 4–5; specific gravity, 4·084; lustre greasy or pearly; colour, yellow to yellowish-white, and sometimes reddish-white; streak yellowish-white to white. It is a product of the oxidation of stibnite, and occurs generally with that mineral—for localities *vide* register of assays.

*Jamesonite.*—Sulphide of antimony and lead, $2 PbS Sb_2 S_3$. Contains 29·5 per cent. of antimony and 50·8 per cent. of lead; most varieties also contain some sulphide of iron. Occurs in acicular crystals, also fibrous-massive, and compact-massive; brittle; hardness, 2–3; specific gravity, 5·5–6; lustre metallic; colour, steel-gray; streak grayish black. Found, according to Liversidge ("Minerals of New South Wales"), with cervantite in a soft quartz near to Campbell Creek and Nuggety Gully, Bathurst District.

*Dyscrasite.*—A silver antimonide, including $Ag_3Sb$, $Ag_{18}Sb$, and other intermediate compounds; massive, granular, and foliated; sectile; hardness, 3·5—4; specific gravity, 9·44—9·85; lustre, metallic; colour and streak, silver-white. Found in considerable masses, up to one ton in weight, in the Australian Broken Hill Consols Lode, where it occurs as pseudomorphs after chalybite. Analyses of a number of samples gave the following results (George Smith):—

| | Silver per cent. | Antimony per cent. | | | |
|---|---|---|---|---|---|
| No. 1 ... ... | 72·9 | 27.1 | agreeing with the formula | | $Ag_3$ Sb |
| No. 2 ... ... | 78·3 | 21·7 | ,, | ,, | $Ag_4$ Sb |
| No. 3 ... ... | 84·4 | 15·6 | ,, | ,, | $Ag_6$ Sb |
| No. 4 ... ... | 91·5 | 8·5 | ,, | ,, | $Ag_{12}$ Sb |
| No. 5 ... ... | 94-1 | 5·9 | ,, | ,, | $Ag_{18}$ Sb |

According to the late General Manager, Mr. George Smith, the dyscrasite has been found in quantities ranging from the smallest of films and crystals to huge blocks weighing over a ton. One piece, on being broken as small as possible for convenience in handling, weighed sixteen cwt., and yielded fine silver equal to 80 per cent., the smelted value of which was over £4,300 (1891). Another piece (according to the same authority) measured *in situ* six feet by four feet at its largest part, and averaged about four inches in thickness. The weight of this was about twenty-three cwt., but its silver value was rather lower. Altogether, over six tons of this mineral was taken from one deposit (prior to 1896), yielding over 142,000 oz. of fine silver, together with other ores, principally stromeyrite, yielding an additional 335,000 oz. In 1899 another important deposit of dyscrasite was found in this interesting mine, and during the present year about two tons of the mineral have been exported.

*Tetrahedrite.*—Argentiferous sulphide of copper and antimony. $4\ Cu_2S\ Sb_2\ S_3$; hardness, 3–4·5; specific gravity, 4·4–5·1; lustre, metallic; colour, between flint-gray and iron-black; contains 24·8 per cent. of antimony. Found in considerable quantities in the Australian Broken Hill Consols Mine. According to Mr. George Smith, the bulk of this ore contained about 20 per cent. of silver. Large quantities were found in siderite, but the richest and largest masses were always found enclosed in calcite.

*Antimonial Silver-chloride.*—A massive mineral substance of a gray colour was found in some quantity in the Australian Broken Hill Consols Mine, and proved to be a mixture of chloride and antimoniate (with probably some antimonite) of silver. Duplicate analyses, made by Mr. J. C. H. Mingaye and Mr. H. P. White, showed that it contained from 16·8 to 20·7 per cent. of antimony, and from 45·8 to 47·5 per cent. of silver. It occurs in conjunction with dyscrasite, and is doubtless an alteration product of that mineral. According to Mr. George Smith, a large mass of the antimonial silver-chloride found in the mine weighed 475 lb.

Other antimonial minerals found in small quantities in the Australian Broken Hill Consols Mine are, *stephanite*, *pyrargyrite*, *brongniardite*, *bournonite*, *bindheimite*, *stibnite*, *stibiconite*, and *willyamite* (sulph-antimonide of nickel and cobalt).

*Uses of Antimony.*—According to Rothwell's "Mineral Industry," antimony is most largely employed in the form of alloys with other metals. To soft metals like lead it gives stiffness and hardness, as in type-metal, Britannia metal, &c. It likewise is used in babbitt-metal for bearings, and for many similar uses. In copper, however, it is one of the most deleterious and dreaded impurities. The native sulphide has been found useful in vulcanising rubber. An admixture of antimony with other metals renders them more lustrous, hard, and brittle. Thus the alloy of antimony and lead containing 86·5 per cent. of lead and 13·5 per cent. of antimony is four times as hard as pure lead, while that containing 64·14 per cent. of antimony is 11·7 times as hard as lead. Hence the use of antimony in type metal, which is an alloy of lead, antimony, and bismuth, containing from 17 to 20 per cent. of antimony. Other important alloys of which antimony forms a part are Britannia metal (10 per cent. antimony and 90 per cent. tin), Pewter (89·3 per cent., 7·1 per cent. antimony, 1·8 per cent. copper, and 1·8 per cent. bismuth), and Argentine (85·5 per cent. tin, and 14·5 per cent. antimony), which is sometimes used for tableware. Antimony also forms a part of antifriction metals employed for machinery. (*Mineral Industry.*)

A new series of antimony alloys were discovered in 1893 and described by D. A. Roche; these are alloys of antimony and aluminium. The alloy containing less than 5 per cent. of antimony is greatly superior to aluminium in hardness, tenacity, and elasticity, and is, at the same time, very malleable. If the percentage of antimony be raised the hardness increases, but the tenacity and elasticity diminish, and when the proportion of antimony exceeds 10 per cent. the alloy crystallises in brilliant laminæ. Aluminium-antimony alloys readily combine with other metals forming complex alloys, some of which are claimed to be susceptible of important industrial applications. Thus, for instance, aluminium-nickel-antimony, or aluminium-tungsten-antimony alloys are remarkable for their great hardness, tenacity, and elasticity; the silver alloys, with or without the addition of nickel or copper, take a very high polish; the alloys with iron, and especially steel, with or without chromium, &c., possess an extremely fine grain, absolutely free from flaws, and are extremely hard and tenacious. (D. A. Roche, *Moniteur Scientifique*, 1893.)

Much antimony in the shape of alloys reaches the market as a by-product in the metallurgy of base bullion.

*Price of Antimony.*—London is the chief market for foreign ores. There are four principal smelting firms in England, viz., Hallett and Fry, Johnson and Matthey, and Pontifex and Wood, in London, and Cookson and Co., at Newcastle-on-Tyne.

The following table shows the lowest and highest prices obtained in the London market for antimony regulus from 1875 to 1898 inclusive. (*Mineral Industry.*)

| Year. | Price. | | Year. | Price. | | Year. | Price. | |
|---|---|---|---|---|---|---|---|---|
| | Lowest. | Highest. | | Lowest. | Highest. | | Lowest. | Highest. |
| 1875 ... | £50 | £59 | 1883 ... | £36 | £40 | 1891 ... | £40 | £72 |
| 1876 ... | 55 | 69 | 1884 ... | 40 | 45 | 1892 ... | 43 | 52 |
| 1877 ... | 48 | 50 | 1885 ... | 35 | 39 | 1893 ... | 37 | 43 |
| 1878 ... | 48 | 50 | 1886 ... | 29½ | 35 | 1894 ... | 32 | 37 |
| 1879 .. | 50 | 70 | 1887 ... | 30 | 40 | 1895 ... | 31½ | 33 |
| 1880 ... | 60 | 75 | 1888 ... | 39 | 50 | 1896 ... | 28½ | 31 |
| 1881 ... | 55 | 60 | 1889 ... | 45 | 75 | 1898 ... | 30 | 37 |
| 1882 ... | 42 | 55 | 1890 ... | 70 | 76 | | | |

*Metallurgy of Antimony.*—Ores of antimony which are mixed with gangue are first hand-picked, after which they are purified by liquation, the sulphide of antimony draining out of the heated ore. In the English process the sulphide is then reduced by fusion with scrap-iron. The ground ore is placed in crucibles which are heated in a long reverberatory furnace furnished by a fireplace at each end communicating with a flue in the middle of the floor of the furnace. The crucibles are lowered to their places on the floor of the furnace through circular holes in the arch. With an ore containing 52 per cent. of antimony the charge for each crucible is made up of 42 lbs. of ground ore, 16 lbs. of wrought-iron scrap, 4 lbs. of common salt, and 1 lb. of skimmings from the next operation, or the same weight of impure slag from a previous melting. About 13 lbs. of the scrap-iron is hammered into a ball sufficiently large to fit the top of the crucible loosely. The balance of the iron, about 3 lbs., is mixed through the ore in the form of turnings or borings. The operation of melting and reduction takes nearly three hours; as the charge melts the ball of iron sinks down and is gradually absorbed by it, being converted into sulphide of iron, while the antimony is reduced to the metallic state. When the reduction is complete the contents of the crucible are poured into a cast-iron mould, which is at once covered with an iron lid. When cold the slag is knocked off the reduced antimony. The metal produced in this first smelting is known as "singles"; it contains 91·63 per cent. of antimony; 7·23 per cent. of iron; and 0·82 per cent. of sulphur. It is necessary to use an excess of iron in order to ensure the reduction of the whole of the antimony, hence the presence of so much iron in the product; the object of the second operation is to remove this excess of iron, and this is accomplished by melting the "singles" with a small quantity of pure sulphide of antimony. The charge in this instance consists of 84 lbs. of "singles," broken small, 7 to 8 lbs. of liquated sulphide of antimony, and 4 lbs. of salt. When fusion is complete the contents of the crucible are skimmed with a long-handled cast-iron ladle, and then poured into a cast-iron mould. The metal resulting from this operation is known as "star bowls." The skimmings are used in the first operation. "Star bowls" contain 99·53 per cent. of antimony; 0·18 per cent. of iron; and 0·16 per cent. of sulphur.

A third operation is necessary in order to remove the sulphur and finally purify the metal. The antimony of commerce, or "Star Antimony" as it is termed, has its surface covered with arborescent or fern-like crystals, and this appearance can only be produced in the pure metal, hence buyers regard the "star" of the antimony as a sign of its purity. In order to obtain "starred" ingots the products of the second operation, or the "star bowls," are melted with what is known as "antimony flux." This latter is made by fusing three parts of ordinary potash with two parts of ground liquated sulphide of antimony. The "star bowls" are first carefully cleaned from all traces of slag, and are then broken small. The charge for the refining process consists of 84 lbs. of "star bowls," and enough "antimony flux" to completely surround the resulting ingots, say about 8 lbs. on the average. The crucibles are placed in the hottest parts of the furnace. The charge of metal is first thrown into the crucible, and as soon as it begins to melt the flux is added. When the fusion is complete the metal is stired round once with an iron rod, and then poured into ingots. The flux is used over and over again for "starring," with the addition of a piece of carbonate of potash each time. The ingots must be completely surrounded with flux, otherwise the metal will not be well "starred" on all sides. When cold the flux can easily be knocked off.

The following is a register of the assays of antimony ores made in the Laboratory of the Department of Mines, Sydney :—

| Locality. | Date of Assay. | Description of Mineral. | Metallic Antimony—per cent. | Gold—per ton. | Silver—per ton. |
|---|---|---|---|---|---|
| | | | | oz. dwt. gr. | oz. dwt. gr. |
| Abercrombie Ranges. (Mount Werong). | 1890 | Stibnite, with quartz .. .. | 54·35 | Nil. | Nil. |
| Armidale District .. .. | 1881 | Antimony ore .. .. .. | 42·95 | 0 1 14 | 0 3 5 |
| ,, ,, .. | ,, | ,, .. .. .. | 32·69 | 0 1 19 | 0 4 0 |
| ,, ,, .. | ,, | ,, .. .. .. | 17·18 | 0 1 14 | 0 4 10 |
| ,, ,, .. | 1882 | ,, .. .. .. | 31·10 | Nil. | Nil. |
| ,, ,, .. | 1885 | Stibnite and cervantite, and a little quartz. | 46 90 | ...... | ...... |
| Armidale, 30 miles north-west of. | 1891 | Stibnite, with a little quartz .. | 58·30 | Nil. | Nil. |
| ,, ,, .. | ,, | Quartz, with stibnite and a little cervantite. | 36·47 | traces. | traces. |
| ,, ,, .. .. | ,, | Stibnite and cervantite .. .. | 54·55 | 4 1 15 | 0 18 8 |
| ,, 8 miles north-west of. | 1897 | ,, ,, .. .. | 64·50 | ...... | ...... |
| Ashford .. .. .. | 1891 | Sulphide and oxide of antimony in quartz. | 42·03 | Nil. | Nil. |
| ,, .. .. .. | ,, | Stibnite, with quartz .. .. | 48·46 | ,, | ,, |
| ,, ... .. .. | ,, | Stibnite .. .. .. .. | 50·72 | ,, | ,, |
| ,, .. .. .. | ,, | Quartz, with stibnite . .. | 31·93 | traces. | traces. |
| ,, .. .. .. | 1892 | Stibnite and cervantite in quartz | 51·07 | ,, | 1 1 18 |
| Barraba, 18 miles north-west of. | 1897 | Stibnite and cervantite .. | 55·00 | ...... | ...... |
| Barraba, 17 miles north of | ,, | Siliceous sulphide and oxide of antimony. | 59·50 | ...... | ...... |
| Bellinger River .. .. | 1885 | Oxide of antimony .. .. .. | 73·19 | ...... | ...... |
| ,, .. .. | ,, | Oxide and sulphide in brecciated veinstone. | 9·58 | ...... | ...... |
| Bellinger River (Peckett Hill). | 1886 | Stibnite .. .. .. .. | 69·97 | ...... | ...... |
| Bellinger River .. .. | 1888 | ,, .. .. .. .. | 66·80 | Nil. | Nil. |
| ,, .. .. | 1890 | Stibnite, with quartz .. .. | 33·80 | ...... | ...... |
| ,, .. .. | ,, | ,, ,, .. .. .. | 43·39 | ...... | ...... |
| Bellinger Heads, 3 miles from. | 1891 | Massive stibnite .. .. .. | 68·62 | traces. | traces. |
| Bellinger River .. .. | ,, | Stibnite, with quartz .. .. | 46·71 | ,, | ,, |
| ,, head of .. | 1893 | Stibnite, with a little cervantite .. | 63·55 | ,, | ,, |
| ,, ,, .. | ,, | Oxide of antimony .. .. .. | 69·94 | Nil. | Nil. |
| ,, ,, .. | ,, | Stibnite and cervantite .. .. | 36·94 | ,, | ,, |
| Bellinger River .. .. | ,, | Fine grained stibnite, with a crust of cervantite. | 79·45 | ,, | ,, |
| ,, .. .. | ,, | Stibnite, with cervantite .. .. | 38·30 | ,, | ,, |
| ,, .. .. | ,, | Oxide of antimony .. .. .. | 41·85 | ,, | ,, |
| ,, .. .. | ,, | Siliceous stibnite, average sample of 5 cwt. | 51·41 | traces. | traces. |
| Bingara .. .. .. | 1878 | Stibnite .. .. .. .. | 48·90 | ...... | ...... |
| ,, .. .. .. | 1884 | ,, .. .. .. .. | 68·68 | Nil. | Nil. |
| ,, .. .. .. | 1885 | Sulphide and oxide, and a little quartz. | 38·18 | ...... | ...... |
| ,, .. .. .. | 1891 | Quartz, with stibnite and cervantite | 45·78 | traces. | traces. |
| ,, 14 miles from .. | ,, | Stibnite .. .. .. .. | 67·72 | Nil. | Nil. |
| ,, .. .. .. | 1892 | ,, .. .. .. .. | 68·85 | traces. | traces. |
| ,, near .. .. | 1894 | Siliceous sulphide of antimony .. | 65·60 | 0 12 22 | 0 12 22 |
| ,, ,, .. .. | ,, | ,, ,, ,, .. | 37·81 | 3 3 3 | 1 6 2 |

| Locality. | Date of Assay. | Description of Mineral. | Metallic Antimony—per cent. | Gold—per ton. | Silver—per ton. |
|---|---|---|---|---|---|
| | | | | oz. dwt. gr. | oz. dwt. gr. |
| Bingara, 23 miles south of. | ,, | Stibnite with quartz .. .. | 39·39 | Nil. | Nil. |
| ,, 20 miles north of. | ,, | Stibnite .. .. .. .. | 68·28 | ,, | ,, |
| ,, near. (Oakey Creek.) | ,, | ,, .. .. .. | 54·07 | ,, | ,, |
| ,, Upper .. .. | ,, | ,, .. .. .. .. | 53·52 | 4 11 10 | 0 10 21 |
| ,, 8 miles from. (Golden Gate.) | 1895 | Stibnite, native antimony, and cervantite. | 72·86 | ...... | ...... |
| Boggabri .. .. .. | 1892 | Stibnite with quartz .. .. | 56·60 | Nil. | trace. |
| Bonshaw, near .. | 1891 | ,, ,, .. | 45·50 | ,, | Nil. |
| Boorook .. .. .. | 1887 | Stibnite .. .. .. | 54·50 | ...... | ...... |
| Bowling Alley Point, near | 1894 | ,, .. .. .. .. | 52·10 | Nil. | Nil. |
| Bowra, near .. | 1889 | ,, with quartz .. .. | 52·81 | ,, | ,, |
| Bowraville .. . .. | 1898 | Cervantite .. .. .. .. | 61·50 | 0 2 12 | ...... |
| ,, .. .. .. | ,, | Stibnite .. .. .. .. | 64·00 | ...... | ...... |
| ,, 1½ mile from. | 1899 | Stibnite, with some oxide and native antimony. | 40·97 | ...... | ...... |
| Bucca Creek .. .. | 1897 | Siliceous sulphide and oxide ore.. | 42·00 | ...... | ...... |
| Bukkulla, near Ashford .. | 1891 | Stibnite in quartz .. .. .. | 47·32 | traces. | traces. |
| Bundarra, 10 miles east of | 1892 | Oxide of antimony in quartz .. | 39·15 | Nil. | 4 15 19 |
| ,, 15 miles north-west of. | 1899 | Sulphide and oxide of antimony.. | 37·85 | ...... | ...... |
| Bungonia .. .. .. | 1880 | Stibnite in quartz .. .. .. | 28·42 | ...... | ...... |
| Cangi .. .. .. | 1898 | Stibnite .. .. .. .. | 52·75 | 0 2 0 | ...... |
| Capertee, 18 miles from. (Razorback.) | 1885 | ,, .. .. .. | 59·73 | 1 18 0 | 1 1 12 |
| ,, ,, .. | ,, | Stibnite with quartz .. | 6·34 | ...... | ...... |
| ,, ,, .. | ,, | ,, ,, .. .. | 58·48 | 2 14 12 | ...... |
| ,, 23 miles from .. | 1892 | Quartz, with sulphide and a little oxide. | 42·85 | 4 13 14 | 0 6 12 |
| Carangula .. .. .. | 1882 | Antimony ore .. .. .. | 50·60 | Nil. | Nil. |
| ,, .. . .. | 1886 | Stibnite and a little quartz .. | 61·55 | 0 5 0 | ...... |
| ,, .. .. .. | ,, | Stibnite and cervantite .. .. | 45·00 | 0 5 0 | ...... |
| Clarence River. (Cattle Station Creek.) | 1890 | Stibnite with quartz .. .. | 24·57 | traces. | ...... |
| Clarence District .. .. | 1891 | Stibnite .. .. .. .. | 46·37 | Nil. | Nil. |
| Clarence River .. .. | 1892 | Stibnite in quartz .. .. .. | 53·60 | traces. | traces. |
| Clarence River District .. | 1893 | Stibnite and cervantite .. .. | 61·98 | ...... | .... |
| ,, ,, .. | ,, | Stibnite with some cervantite .. | 54·23 | ...... | ...... |
| ,, ,, .. | 1893 | Stibnite .. .. .. .. | 68·58 | ...... | ...... |
| ,, ,, .. | ,, | ,, .. .. .. | 61·14 | Nil. | Nil. |
| Cobar, 40 miles from .. | 1895 | Siliceous stibnite .. .. | 59·98 | 0 9 19 | 0 3 6 |
| Coolongolook and Manning River. | 1881 | Antimony ore .. .. | 32·52 | traces. | 0 4 13 |
| ,, 6 miles from Wanga. | 1886 | Stibnite and quartz .. . .. | 31·29 | ...... | ...... |
| ,, .. .. | 1889 | ,, ,, .. .. .. | 41·32 | Nil. | Nil. |
| ,, .. .. | 1890 | ,, ,, .. .. .. | 21·75 | ...... | ...... |
| ,, .. .. | 1893 | Stibnite .. .. . .. | 57·61 | Nil. | Nil. |
| ,, (Wang Wauk) | ,, | ,, .. .. . .. | 46·78 | ,, | ,, |
| Copmanhurst, 25 miles from. | 1890 | Stibnite with a little quartz .. | 55·34 | traces. | 1 12 16 |
| ,, 25 miles from. | ,, | Quartz with sulphide and a little oxide of antimony. | 26·84 | ,, | 1 1 16 |
| Crudine .. .. .. | 1884 | Oxide of antimony .. .. .. | 62·43 | Nil. | Nil. |
| ,, .. .. .. | 1886 | Breccia from antimony lode .. | 48·80 | ...... | ...... |
| ,, Creek .. .. | 1890 | Stibnite with quartz .. .. | 55·57 | traces. | ...... |
| Cudgegong .. .. | 1884 | Stibnite with crust of cervantite.. | 33·38 | Nil. | Nil. |
| ,, . .. | ,, | Cervantite with a little stibnite .. | 61·40 | traces. | 1 12 12 |
| ,, River.. .. | 1893 | Siliceous antimony ore .. .. | 41·21 | Nil. | Nil. |
| Drake .. .. .. | 1891 | Stibnite with a little quartz .. | 60·63 | ,, | ,, |
| Duckmaloi River .. .. | 1899 | Sulphide of lead and bismuth (cosalite). | 0·55 | 1 9 6 | 252 10 4 |
| Dungog Creek .. | 1891 | Stibnite with quartz .. .. | 50·80 | Nil. | Nil. |
| Duval .. .. | 1897 | Stibnite and cervantite .. .. | 60·00 | ...... | ...... |

| Locality. | Date of Assay. | Description of Mineral. | Metallic Antimony—per cent. | Gold—per ton. | Silver—per ton. |
|---|---|---|---|---|---|
| | | | | oz. dwt. gr. | oz. dwt. gr. |
| Gara, 12 miles from Armidale. | 1880 | Stibnite .. .. .. .. | 57·59 | Nil. | Nil. |
| Glen Elgin River .. .. | 1882 | Antimony ore.. .. .. .. | 35·16 | ,, | ,, |
| Glen Innes .. .. .. .. | 1881 | ,, ,, .. .. .. .. | 16·50 | ...... | ...... |
| ,, District .. | 1897 | Stibnite and cervantite .. .. | 64·50 | ...... | ...... |
| Grafton .. .. .. | 1890 | Stibnite with a little quartz .. | 30·15 | traces. | traces. |
| ,, District .. .. | 1891 | Quartz with oxide and sulphide of antimony. | 26·86 | Nil. | 0 10 21 |
| Gulgong .. .. .. | 1886 | Oxide of antimony .. .. | 68·90 | ...... | ...... |
| ,, (head of Ford's Creek.) | ,, | Antimony breccia . .. .. | 36·30 | ...... | ...... |
| ,, 2 miles from .. | ,, | Stibnite and a little quartz .. | 27·50 | ...... | ...... |
| Guyra River .. .. | 1889 | Stibnite with quartz .. .. | 42·66 | Nil. | Nil. |
| Hell's Hole (Mudgee line) | 1883 | Stibnite .. .. .. .. | 40·26 | 2 10 0 | traces. |
| Hillgrove (Eleanora Mine) | ,, | ,, .. . .. .. | 57·00 | 2 12 0 | 0 19 12 |
| ,, (Garibaldi Claim) | ,, | Stibnite in vein stuff .. .. | 39·90 | traces. | traces. |
| ,, (Eleanora Mine).. | ,, | Stibnite from vein in dyke .. | 67·26 | traces. | Nil. |
| ,, .. .. .. | 1889 | Stibnite with quartz .. .. | 52·60 | 2 2 10 | ...... |
| ,, (Baker's Creek).. | ,, | ,, ,, ,, .. .. | 72·55 | Nil. | ...... |
| ,, near .. .. | ,, | ,, ,, ,, .. .. | 44·05 | trace. | ...... |
| ,, ,, .. .. | 1890 | Stibnite .. .. .. .. | 64·26 | ...... | ...... |
| ,, ,, .. .. | 1890 | Quartz, with breccia of quartz and slate carrying stibnite. | 25·26 | 4 3 19 | 0 16 8 |
| ,, ,, .. .. | ,, | Concentrates .. .. .. .. | 22·61 | 3 14 1 | 1 6 2 |
| ,, ,, .. .. | 1891 | Sulphide, with a little oxide of antimony. | 70·82 | Nil. | Nil. |
| ,, (West Sunlight G.M. Co.) | 1893 | Stibnite .. .. .. | 50·67 | ...... | ...... |
| ,, District .. .. | 1894 | Siliceous stibnite .. .. .. | 30·27 | Nil. | 5 19 15 |
| Ilford, near. (Old Razorback.) | 1882 | Antimony ore.. .. .. .. | 30·42 | Nil. | Nil. |
| Kempfield .. .. .. | 1899 | Stibnite .. .. .. .. .. | 61·18 | ...... | ...... |
| Kempsey District.. .. | 1880 | Veinstuff impregnated with sulphides of antimony and iron. | 21·88 | ...... | ...... |
| ,, ,, .. .. | 1889 | Stibnite .. .. .. .. .. | 60·50 | trace. | ...... |
| ,, ,, .. .. | ,, | Stibnite with quartz and black slate | 43·02 | trace. | ...... |
| ,, ,, .. .. | ,, | Native antimony .. .. .. | 90·78 | ,, | ...... |
| Lismore .. .. .. | 1888 | Stibnite with a little quartz .. | 45·50 | Nil. | 10 1 12 |
| Lionsville. (Washpool Creek.) | 1893 | Stibnite .. .. .. | 56·10 | ,, | 0 14 0 |
| Lucknow .. .. .. | 1884 | Calcite with native antimony .. | 38·75 | 8 9 12 | 1 12 12 |
| Lunatic Reef .. | 1893 | Cervantite and stibnite .. .. | 50·84 | Nil. | Nil. |
| Lyndhurst .. .. .. | 1890 | Stibnite with a little quartz .. | 55·71 | Nil. | Nil. |
| Macksville. (Mountain Maid Mine.) | 1893 | Stibnite .. . .. | 66·31 | Nil. | Nil. |
| ,, .. .. .. .. | ,, | Felspathic antimony ore .. .. | 27·57 | ...... | ...... |
| ,, District .. | ,, | Stibnite with felspathic matter .. | 52·30 | traces. | traces. |
| ,, ,, .. .. | ,, | ,, ,, ,, ,, .. | 56·21 | ,, | ,, |
| Macleay River. (The Watershed.) | 1884 | Stibnite and cervantite .. .. | 63·69 | Nil. | Nil. |
| ,, ,, (Upper) | 1899 | Stibnite .. .. .. .. | 56·28 | ...... | ...... |
| ,, ,, ,, .. | ,, | Siliceous antimony ore (oxide) .. | 21·63 | ...... | ...... |
| ,, ,, ,, .. | ,, | Sulphide and some oxide, with a little quartz. | 42·47 | ...... | ...... |
| ,, ,, ,, .. | ,, | Stibnite with quartz .. .. | 28·89 | ...... | ...... |
| Manilla District .. .. | 1899 | ,, ,, ,, .. .. | 48·57 | ...... | ...... |
| Marulan. (Carrington Mine.) | 1886 | Suphide and oxide of antimony with galena and quartz. (Pb. = 22·27 %). | 16·75 | 2 17 0 | 164 3 0 |
| McDonald River, the head of. | 1886 | Quartz and stibnite .. .. .. | 43·75 | ...... | ...... |
| Mole River .. .. .. | 1890 | Stibnite with quartz .. .. | 51·78 | Nil. | Nil. |
| Mudgee District .. .. | 1887 | Galena and stibnite.. .. .. | 50·36 | ...... | ...... |
| Nambucca (west of Bowra) | 1888 | Stibnite with a little quartz .. | 64·30 | Nil. | Nil. |

| Locality. | Date of Assay. | Description of Mineral. | Metallic Antimony—per cent. | Gold—per ton. | Silver—per ton. |
|---|---|---|---|---|---|
| Nambucca District .. | 1889 | Stibnite in claystone .. .. | 32·82 | traces. | traces. |
| „ (Deep Creek).. | „ | Stibnite and oxide of antimony, with quartz. | 47·96 | Nil. | Nil. |
| „ „ „ .. | „ | Native antimony .. .. .. | 95·54 | traces. | traces. |
| „ „ „ .. | „ | Stibnite with quartz and slate .. | 23·49 | „ | „ |
| „ „ .. | „ | „ .. .. .. .. | 66·02 | Nil. | Nil. |
| „ „ .. | „ | Stibnite with quartz.. .. .. | 47·92 | „ | „ |
| „ Taylor's Arm) | „ | „ „ .. .. | 53·13 | traces. | traces. |
| „ „ .. | „ | Stibnite and cervantite .. .. | 53·60 | „ | „ |
| „ „ .. | „ | Stibnite .. .. .. .. | 61·85 | Nil. | Nil. |
| „ .. .. .. | 1891 | „ .. .. .. .. | 60·72 | „ | „ |
| „ .. .. .. | „ | „ .. .. .. .. | 39·19 | „ | „ |
| „ .. .. .. | „ | Quartz with stibnite .. .. | 57·14 | traces. | 0 5 10 |
| „ River (Taylor's Arm.) | 1892 | Stibnite with quartz .. .. | 25·02 | Nil. | Nil. |
| „ „ „ .. | „ | Stibnite .. .. .. . | 67·48 | „ | „ |
| „ „ „ .. | „ | Quartz with stibnite .. .. | 59·85 | „ | „ |
| „ „ „ | „ | Stibnite with native antimony .. | 80·98 | „ | „ |
| „ „ „ .. | „ | Quartz with stibnite .. .. | 37·46 | „ | „ |
| „ „ .. .. | „ | Stibnite .. .. .. .. | 58·07 | „ | „ |
| „ „ .. .. | „ | Finely crushed concentrated stibnite. | 64·23 | traces. | traces. |
| „ „ (Bull Ck.) | „ | Stibnite .. .. .. .. | 55·22 | ...... | ...... |
| „ „ „ .. | „ | „ .. . .. .. | 69·53 | traces. | traces. |
| „ Heads (7 miles from Bowra.) | 1895 | „ .. .. .. .. | 62·55 | ...... | ...... |
| „ River (Upper Taylor's Arm) | 1899 | „ .. . .. .. | 63·10 | ...... | ...... |
| Nana Creek.. .. .. | 1893 | „ .. . .. .. | 30·00 | trace. | 1 12 16 |
| Nerriga .. .. .. | 1885 | Quartz with stibnite .. .. | 22·43 | ...... | ...... |
| New England .. .. | 1882 | Antimony ore .. .. .. | 70·60 | Nil. | Nil. |
| „ (Reedy Ck.) | 1890 | Galena, zincblende, mispickel, stibnite, and a little oxide of antimony in quartz (Pb = 14·93 %.) | 11·24 | „ | 28 17 2 |
| Nundle .. .. .. | 1891 | Stibnite with felsitic gangue .. | 60·57 | „ | Nil. |
| „ .. .. .. | „ | Fine-grained stibnite .. .. | 58·84 | „ | „ |
| „ .. .. .. | „ | Stibnite . .. .. | 55·79 | „ | „ |
| „ .. . .. | „ | „ .. .. . .. | 63·31 | „ | „ |
| „ near (Peel River) | 1892 | Stibnite with quartz .. .. | 45·75 | „ | „ |
| „ .. .. | „ | Stibnite with a little quartz .. | 57·96 | 0 6 12 | 0 15 2 |
| „ .. .. .. | „ | Stibnite and cervantite .. .. | 52·97 | Nil. | Nil. |
| „ .. .. .. | „ | Stibnite and quartz .. .. | 36·03 | traces. | traces. |
| „ .. .. .. | „ | „ „ .. .. | 50·07 | „ | „ |
| „ near .. .. | 1893 | Stibnite with a little cervantite and quartz. | 59·87 | Nil. | Nil. |
| Nuntherungie .. .. | 1892 | Quartz with stibnite and cervantite. | 25·15 | „ | „ |
| Oban.. .. .. .. | 1894 | Sulphide and oxide of antimony .. | 26·52 | traces. | traces. |
| Paterson District .. .. | 1880 | Stibnite in quartz .. .. .. | 23·87 | 0 2 10 | „ |
| „ .. .. | 1891 | „ „ .. .. .. | 32·44 | Nil. | Nil. |
| Peelwood (Hunt's Creek).. | 1885 | Oxide and sulphide of antimony .. | 23·44 | ...... | ...... |
| Pyramul .. .. .. | 1875 | Stibnite with cervantite .. .. | 67·74 | traces. | traces. |
| Razorback, 9 miles from.. | 1886 | Oxide and sulphide of antimony .. | 67·30 | ...... | ...... |
| „ 8 miles from (Back Creek) | „ | Ferruginous sulphide and oxide of antimony. | 55·33 | ...... | ...... |
| Rocky River .. .. | 1885 | Oxide and sulphide of antimony .. | 11·60 | ...... | ...... |
| Shoalhaven.. .. .. | 1886 | Quartz and stibnite .. .. .. | 28·52 | | |
| Sofala .. .. .. | „ | „ „ .. .. .. | 46·30 | 0 14 12 | 0 7 12 |
| Stony Batta (New England) | 1888 | Stibnite with a little quartz .. | 55·71 | Nil. | 44 2 0 |
| Talbragar .. .. .. | 1886 | Oxide of antimony .. .. .. | 70·40 | ...... | ...... |
| Tamworth District .. | 1891 | Stibnite in quartz .. .. | 48·39 | Nil. | Nil. |
| Tamworth and Crow Mountain, between. | 1898 | Stibnite .. .. .. | 68·00 | ...... | ...... |
| Temora .. .. | 1886 | Quartz and stibnite .. .. .. | 34·14 | 3 16 0 | ...... |

| Locality. | Date of Assay. | Description of Mineral. | Metallic Antimony—per cent. | Gold—per ton. | Silver—per ton. |
|---|---|---|---|---|---|
| Tingha .. . .. | 1899 | Granitic rock containing ores of antimony and bismuth. | 1·55 | ...... | ...... |
| Two-mile Flat .. .. | 1888 | Stibnite in quartz .. .. .. | 29·36 | traces. | Nil. |
| Ulmarra (Clarence River) | 1897 | Radiating crystals of oxide of antimony. | 63·00 | 0 2 0 | 1 10 0 |
| Uralla, near .. .. | 1880 | Sulphide of antimony, with a little oxide. | 56·41 | traces. | traces. |
| Walcha .. .. | 1884 | Quartz with stibnite .. .. | 40·20 | ,, | 24 18 0 |
| ,, near .. .. | 1892 | Stibnite .. .. .. .. | 53·18 | Nil. | Nil. |
| Wang Wauk, near Foster | 1894 | ,, .. .. .. | 34·71 | traces. | traces. |
| Warialda, 15 miles south of | 1894 | ,, .. .. .. .. | 69·64 | 0 6 12 | 0 12 22 |
| ,, 6 miles from .. | 1899 | Sulphide and oxide of antimony .. | 51·07 | ...... | ...... |
| ,, 6 ,, .. | ,, | Oxide of antimony, with a little sulphide. | 48·82 | ...... | ...... |
| Williams River (20 miles north of Dungog). | 1884 | Stibnite .. .. .. .. | 52·64 | 0 4 0 | 3 5 0 |
| Yulgilbah (County Drake) | 1882 | Antimony ore .. .. .. | 49·50 | Nil. | Nil. |
| ,, ( ,, ) | 1893 | Stibnite with a little quartz .. | 51·85 | ,, | ,, |
| ,, ( ,, ) | ,, | Stibnite with quartz .. .. | 54·07 | ,, | ,, |

## Production of Antimony (Ore Regulus and Metal).

| Year. | Quantity. | Value. |
|---|---|---|
| To end of | Tons. | £ |
| 1880 | 564·35 | 11,830 |
| 1881 | 539·20 | 17,346 |
| 1882 | 1,068·90 | 16,732 |
| 1883 | 375·55 | 5,555 |
| 1884 | 433·60 | 6,458 |
| 1885 | 292·75 | 4,296 |
| 1886 | 273·15 | 3,381 |
| 1887 | 168·35 | 1,641 |
| 1888 | 190·35 | 2,918 |
| 1889 | 221·40 | 3,344 |
| 1890 | 1,026·00 | 20,240 |
| 1891 | 914·85 | 22,057 |
| 1892 | 728·25 | 14,680 |
| 1893 | 1,774·00 | 25,092 |
| 1894 | 1,250·35 | 18,744 |
| 1895 | 478·80 | 7,251 |
| 1896 | 132·75 | 1,834 |
| 1897 | 169·10 | 3,612 |
| 1898 | 82·35 | 916 |
| 1899 | 326·50 | 2,694 |
| Totals ... ... | 11,010·55 | 190,621 |

# BISMUTH.

Bismuth is a comparatively rare metal, and, although its ores are known to occur in a considerable number of places in New South Wales, they have only been found in quantity in two or three localities, such as Kingsgate, near Yarrow Creek, about 18 miles to the east of Glen Innes, and the Jingera Mineral Proprietary mines, Whipstick, 14 miles west of Panbula.

*Uses of Bismuth.*—According to Rothwell's *Mineral Industry,* "bismuth is used in the metallic form only in alloys, but its salts are employed extensively for various purposes; thus the oxide, with boric and silicic acids, is used for optical glasses, and to a considerable extent for porcelain colours, while the basic nitrate is used as a cosmetic, and also in medicine. The alloys of bismuth are remarkable for their ready fusibility and their property of expanding on solidification. Bismuth forms alloys with nearly all the other metals, but the following are the most important in the arts:—Newton's Fusible Metal, which melts at 94·5° C., is composed of 8 parts bismuth, 3 parts tin, and 5 parts lead; Darcet's Metal contains 2 parts bismuth, 1 part lead, and 1 part tin, melting at 93° C.; another alloy with 5 parts bismuth, 2 parts tin, and 3 parts lead, melts at 91·6° C.; Rose's Metal, containing 420 parts bismuth, 236 parts lead, and 207 parts tin, fuses below 100° C., and on cooling remains pasty for a considerable range of temperature below that point. This alloy has other curious properties; it expands regularly with heat from zero to 35° C., but on further heating it contracts up to 55°, from which point up to 80° the rate of expansion is more rapid than below 35°. Above 80°, however, the normal rate is resumed."

The fusibility of bismuth alloys is increased by the addition of cadmium; thus Wood's Fusible Metal, containing a small proportion of cadmium, melts between 66° and 71° C., while Lipowitz's Metal, containing 8 parts lead, 15 parts bismuth, 4 parts tin, and 3 parts cadmium, softens at about 55° C., and is completely liquid at a little over 60°.

"Fusible alloys containing bismuth have been used to some extent as safety plugs for steam boilers, but it has been found that these are untrustworthy, owing to the liquation of the more fusible components of the mass when subject to continued heating near, but below, the melting point, leaving a more refractory alloy behind. More recently these alloys have found an application in the automatic sprinklers placed on the ceilings of buildings as protection against fire, the sprinkler-plugs melting with a rise in temperature above the safety point, and allowing the water to flow from the sprinklers."

Owing to the limited demand for bismuth, over-production would speedily result, and would be accompanied by a lowering of its value, were it not for the fact that the market is controlled by a "ring," or syndicate, in Europe.

*Ores of Bismuth.*—The following are the principal ores of bismuth:—

*Native Bismuth*, or metallic bismuth.—Colour, silver-white, with a reddish hue ; lustre, metallic ; brittle ; hardness, 2-2·5 ; specific gravity, 9·70—9·83 ; melts at a temperature of 507° F.

*Bismuthinite* (*or Bismuthine*), or *sulphide of bismuth* ; $Bi_2\ S_3$ ; massive, with a fibrous or foliated structure ; contains 81·2 per cent. of bismuth with sometimes a little copper and iron ; hardness, 2 ; specific gravity, 6·4—6·5 ; streak and colour, lead-gray, inclining to tin-white, with a yellowish or iridescent tarnish.

*Bismutite*, or *carbonate of bismuth* ; $Bi_2\ O_3\ CO_2\ OH_2$ ; contains 80·68 per cent. of bismuth, when pure ; hardness, 4—4·5 ; specific gravity, 6·86—6·9 ; colour, white, straw-yellow, and yellowish-gray to green ; streak, greenish-gray to colourless.

*Bismuth Ochre*, or *Bismuth Trioxide*, $Bi_2\ O_3$ ; contains 89·6 per cent. of bismuth ; not crystallised ; massive, and earthy ; specific gravity, 4·361 ; colour, greenish-yellow, straw-yellow, grayish-white.

*Tetradymite*, telluride of bismuth, with sometimes sulphur, $Bi_2\ (Te, S)_3$ ; crystallises in rhombohedral forms, also foliated to granular massive ; hardness, 1·5—2 ; specific gravity, 7·2—7·6 ; colour, pale steel-gray ; lustre metallic, splendent.

*Metallurgy of Bismuth.*—A wet method is now generally employed in the treatment of bismuth concentrates. The ore as it comes from the mines is crushed and concentrated, the concentrates being then roasted in a reverberatory furnace to get rid of the sulphur and any arsenic that may be present. The roasted ore is then treated for about six hours with dilute muriatic acid (one part of acid to one of water), after which the solution is drawn off into other vessels in which it is mixed with an excess of water, which precipitates the bismuth as oxychloride. If iron be present in any quantity the oxychloride of bismuth has a yellow colour instead of being pure white, and it is then necessary to redissolve it in muriatic acid, and again precipitate it by diluting the solution with water. It may be necessary to repeat the precipitation a third time before the iron is completely got rid of. The bismuth of commerce is then prepared by fusing the washed and dried oxychloride in a graphite crucible with lime, charcoal, and a proportion of the slag resulting from previous fusions.

*The Kingsgate bismuth deposits* are situated near the Yarrow Creek, at Kingsgate, about 18 miles east of Glen Innes. The geological formations at Kingsgate consist of granite and indurated claystones of Carboniferous age, forming rough broken country with valleys about 500 feet deep. The bismuth ore deposits are situated in the granite in proximity to the line of its junction with the claystones. The deposits themselves are unique in their mode of occurrence. They consist of pipe veins, which are roughly circular or oval in section, and which dip to the east or north-east, *i.e.*, towards the junction of the granite and claystone, at an average angle of about 30°. Occasionally, in their course, they descend vertically for short distances, and one vein was vertical at its outcrop, but most of them outcrop at a low angle. Many of the pipes appear at the surface in several branches or heads, which at a depth of 30 or 40 feet unite into one main cylindrical ore body. These main pipe veins vary from 10 to 50 feet in diameter, and as a rule they have been found to increase in size as they are followed down. One of the pipes was worked for a distance of 460 feet on the underlie, and when mining operations in it were abandoned it still contained good ore, and was about 26 feet in diameter. According to a survey by Mr. W. H. Yates, the Manager of the Kingsgate Bismuth and Silver-mining Company, the following table shows the direction, distance, and dip of this pipe (No. 13) from its outcrop to the point at which work was stopped :—

| Direction. | Distance in feet. | Angle of dip. |
|---|---|---|
| N. 37° E. ... ... | 52 | 42° |
| S. 76° E. ... ... | 56 | 32° |
| S. 43° E. ... ... | 22 | horizontal. |
| N. 61° E. ... ... | 83 | 26° |
| S. 71° E. ... ... | 30 | 30° |
| S. 62° E. ... ... | 21 | 40° |
| N. 32° E. ... ... | 17 | 42° |
| S. 47° E. . .. | 27 | 37° |
| N. 10° E. ... ... | 26 | 18° |
| N. 68° E. ... ... | 36 | 37° |
| N. 77° E. ... ... | 32 | 20° |
| N. 35° E. ... ... | 58 | 44° |
| | 460 | |

Another pipe whose diameter was from 30 to 40 feet, was followed in an easterly or north-easterly direction for 129 feet, when it turned under and dipped to the north-west, but after being followed in this direction for 20 feet it again resumed an easterly course. The following is a record of Mr. Yates' survey of the pipe (No. 8) :—

| Direction. | Distance in feet. | Angle of dip. |
|---|---|---|
| N. 82° E. ... ... | 37 | 27° |
| N. 2° E. ... ... | 30 | 21° |
| N. 52° E. ... ... | 28 | 30° |
| N. 29° E. ... ... | 34 | 42° |
| N. 46° W. ... ... | 20 | 26° |
| N. 64° E. ... ... | 52 | 3° |
| N. 75° E. ... ... | 57 | 30° |
| S. 84° E. ... ... | 33 | 44° |

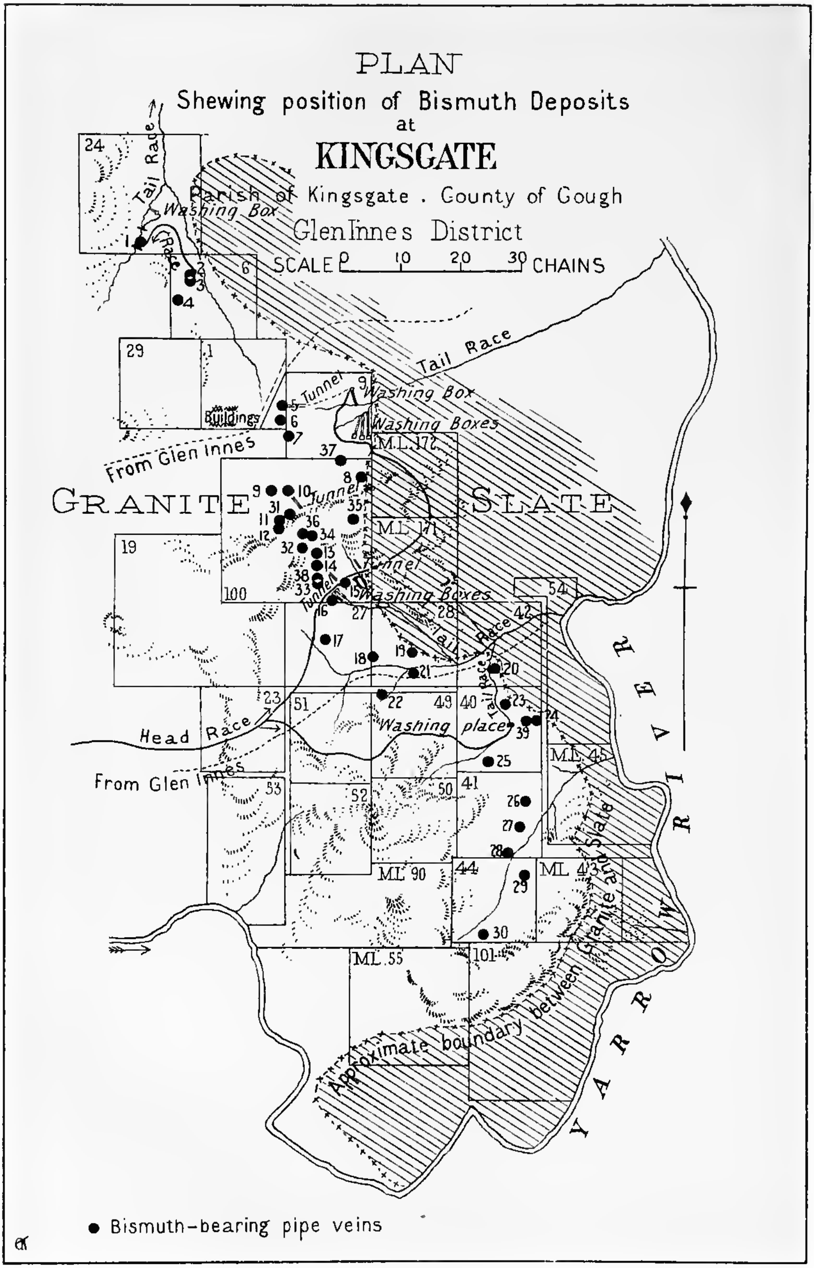



Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

The accompanying plan of the deposits has been compiled from surveys by Mr. W. H. Yates, the Manager of the Kingsgate Mines. It will be seen that no less than thirty-nine pipe-veins have been discovered in the granite, within a short distance of its junction with the claystones, and it is probable that careful prospecting would disclose many others.

The gangue of the veins is composed of quartz, and this is abundantly impregnated with molybdenite in large crystals, some of them three inches in diameter, while the bismuth, which is not so plentiful, occurs as carbonate and oxide, principally in the joint fissures in the quartz near the surface, and as sulphide and native bismuth in the solid quartz at greater depths. Both gold and silver are contained in the bismuth ore, and in some of the pipe veins mispickel and wolfram have also been found. Large crystals (as much as eighteen inches in length) of very clear quartz, suitable for optical purposes, occur in vughs in some of the veins, and crystals of smoky quartz are also common. In some instances long delicate needles of native bismuth, and also of sulphide of bismuth, are enclosed in a matrix of perfectly transparent quartz. Occasionally masses of native bismuth have been found between crystals of quartz in the veins, and when removed have shown the impress of the quartz crystals. An average sample of the ore, taken by Mr. Wilkinson in 1883, yielded by assay :—

Metallic bismuth, 2·6 per cent.
Fine gold, at the rate of 8 dwt. per ton.
Silver, at the rate of 3 oz. 5 dwt. per ton.

A sample of the concentrated ore, taken at the same time, yielded as follows :—

Metallic bismuth, 69·3 per cent.
Fine gold, at the rate of 4 oz. 1½ dwt. per ton.
Silver, at the rate of 57 oz. 3 dwt. per ton.

The ore in the pipe-veins contains from ½ to 5 per cent. of bismuth. Eleven out of the thirty-nine pipe-veins known to exist on the Kingsgate Company's property have been opened and worked since the year 1879, and the following is a statement of the amount of ore won from them.

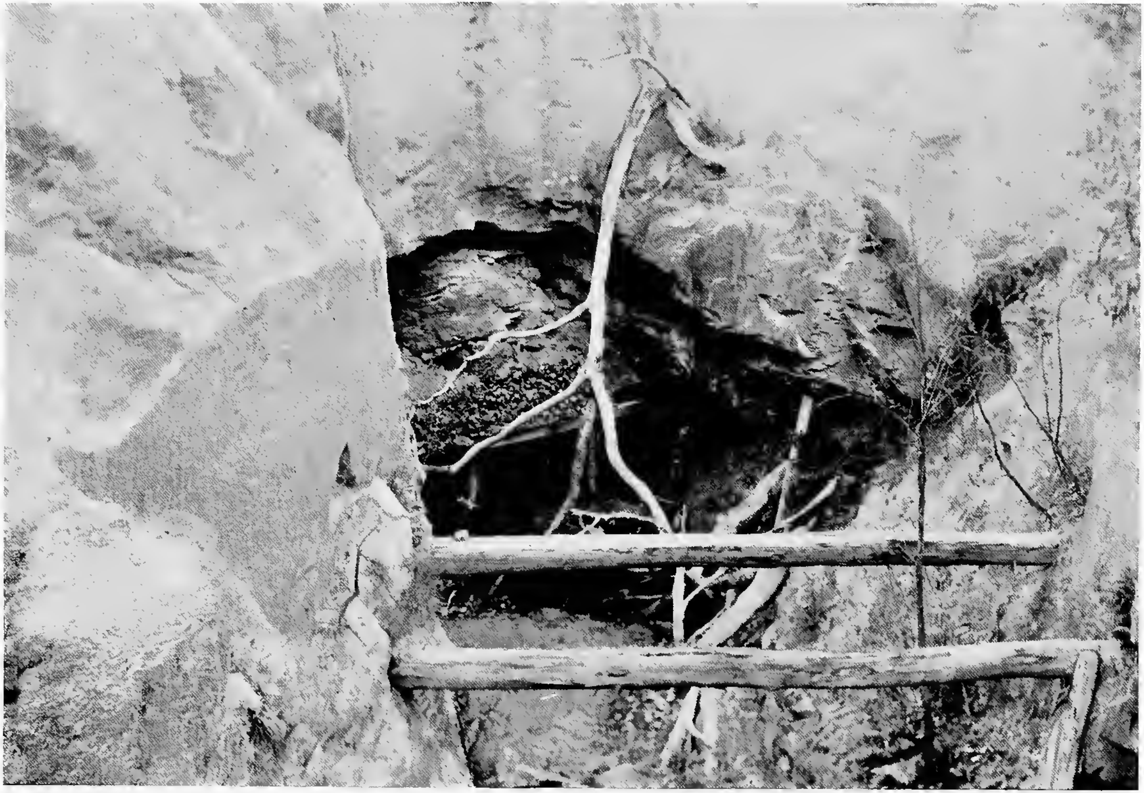
| Year. | Concentrated bismuth ore. | Metallic bismuth. | Molybdenite. |
|---|---|---|---|
| | Tons. | Tons. | |
| 1879 to 1883 ... ... | 30 | 14 | Nil. |
| 1884 ... ... ... ... | 15 | 8 | Nil. |
| 1885 ... ... ... ... | 36 | 18 | 2 |
| 1886 ... ... ... ... | 37 | 18 | Nil. |
| 1887 ... ... ... ... | 40 | 16 | Nil. |
| 1888 ... ... ... ... | 50 | 18 | 2 |
| 1889 ... ... ... ... | 42 | 18 | Nil. |
| 1894 to 1898 ... ... | ...... ... | ......... | 36 |
| | 250 | 110 | 40 |

In exploiting the deposits, the custom has been to follow each pipe-vein from the surface by means of an open cut, and, when this became too deep for convenient working, to sink shafts to strike the vein on the dip, or drive tunnels from the hill sides to intersect it; then, when the cost of extraction by these means became too great, the workings were abandoned, and operations commenced on the outcrop of another pipe-vein. In consequence of this custom, none of the deposits have been worked out, and, as already stated, only eleven out of the thirty-nine known to exist have been opened.

The production has been regulated by market requirements, and not by the capacity of the mines. Active mining operations practically ceased at the end of the year 1889, though a small amount of work has been done since that date by tributers. Of recent years, the price of bismuth has been very low, only 3s. per lb. having been obtained for the metal in London, after all charges were paid, as against 7s. 6d. which was the ruling price for some time previously. At this rate the deposits did not pay to work, but quite recently there has been a considerable improvement in the price of the metal, and a reopening of the mines may be expected.

The method of concentrating the mineral, as hitherto practised, is rough and very wasteful. The ore was first hand-picked at the mine, and was then carted about half a mile to the concentrating works. Here it was put through a Blake crusher, driven by a water-wheel. It was generally crushed twice, or until it all passed through the grating of an inclined trommel having a mesh of four holes to the inch. The crushed material was then treated in a sluice-box having a fall of 9 inches in a length of 12 feet. While being sluiced it was worked gently with a shovel, and also with a birch broom, and by these means concentrates of 20 per cent. grade were obtained. These concentrates were then again treated in a smaller sluice-box with a slighter fall, and in this way they were cleaned to a 50–60 per cent. tenor. The finely crushed molybdenite was all got rid of by gently stirring the contents of the sluice-box with the shovel and broom; the concentrates were afterwards dried and sifted, and the coarser fragments of molybdenite picked out by hand. The ore thus cleaned was exported.

Similar veins occur in land adjoining the Kingsgate Company's property on the south, but these are not at present being worked. The following extracts are from a report by the late Mr. C. S. Wilkinson, Geological Surveyor-in-Charge, who inspected these deposits in 1883:—
"The Glen Innes Company is now sinking upon a vein which is said to be 1 foot wide at the surface, but when I saw it at a depth of 40 feet, the lowest level then reached, it was 4 feet wide. This vein is in granite, and close to the boundary of the slate formation. The vein stuff is thickly studded with large, brilliant, steel-grey plates of molybdenite, some of them being more than 3 inches in diameter. Nodules



*Photographed by E. F Pittman.*

BISMUTH-BEARING PIPE-VEIN IN GRANITE (DEPOSIT NO. 5) KINGSGATE, NEAR GLEN INNES.

of native bismuth, larger than walnuts, with carbonate, sulphide, and oxide of bismuth, occur through the vein, and in greater quantity in places where the molybdenite becomes abundant."

"Another vein situated about 100 yards from this contains besides bismuth ore and molybdenite, some arsenical pyrites, which latter yielded on assay 9·2 per cent. of metallic bismuth, fine silver at the rate of 92 oz. 14 dwt. per ton, and no gold."

"About three miles from the Yarrow Creek Head Station, and about the same distance in a south-easterly direction from Kingsgate, is the Comstock Bismuth Company's mine. No work was being done here at the time of our visit, but we saw three pipe-veins of hard, white crystalline quartz which had been opened for only a few feet from the surface. The shafts were partly filled with water, so that the exact size of the veins could not be measured, but the largest of them appeared to be about 6 feet by 15 feet near the surface. A sample of bismuth ore collected from the heaps gave on assay :—

"Metallic bismuth ... ... ... 35·6 per cent.
"Fine gold at the rate of 2 oz. 9 dwt. per ton.
"Fine silver at the rate of 9 oz. 16 dwt. per ton.

"Thus, again, we see that the bismuth ore contains gold. These veins are also in granite, and about 200 yards distant from the slate formation."

"It is a somewhat remarkable feature that all the bismuth veins as yet found occur in the granite within a short distance from the slate ; and it is probable that on further examination of the country along the line of junction of the two formations other veins will be discovered. The bismuth lode in the Silent Grove mine occurs under the same conditions, viz., in granite, close to its junction with altered slates, and it is of similar character to those above described."

"Some of the lodes at Kingsgate were originally taken up in 1871 for *tin* mining, but it is said that J. Feeny, a stockman on the Yarrow Creek station, was the first discoverer of the bismuth, in the year 1877."

Quite recently bismuth-bearing pipe-veins of precisely similar character have been discovered at Pheasant Creek, over thirty miles distant in a N.N.E. direction from Kingsgate. It is evident therefore that these deposits are spread over a considerable area of country, and it is probably only the extremely rough character of the country that has prevented the finding of many other similar pipe-veins.

*The Jingera Mineral Proprietary Mines.*—These mines are situated at Whipstick (near Wyndham), about fourteen miles to the west of Panbula, and are at the present time producing nearly all the bismuth raised in New South Wales. In their character and mode of occurrence the deposits are very similar to those of Kingsgate and Pheasant Creek from which they are distant about five hundred miles. They consist of more or less cylindrical pipe-veins, which have a very irregular course and inclination, and which intersect granite rocks in proximity to their junction with slate. The filling of the pipes, however, instead of consisting entirely of quartz, as is the case at Kingsgate, is composed of a coarsely crystalline admixture of felspar and quartz, with a little mica, and occasional bunches of garnet rock. At least six of these pipes have been found, and they are all situated in proximity to a dyke (about four or five feet wide) of trachyte, which intersects the granite. The maximum diameter of the pipes is about fifteen or twenty feet, and the area within which they have, so far, been proved to occur is about two acres. The minerals which occur disseminated through the matrix are native bismuth, sulphide of bismuth, carbonate and trioxide of bismuth, and molybdenite. No wolfram has been found in these deposits. Quite recently a fine patch of native bismuth, weighing four hundredweight, was found associated with white quartz, in one of the pipes, but as a rule the sulphide is the most common ore met with at a depth, while the carbonate and oxide occur near the surface.

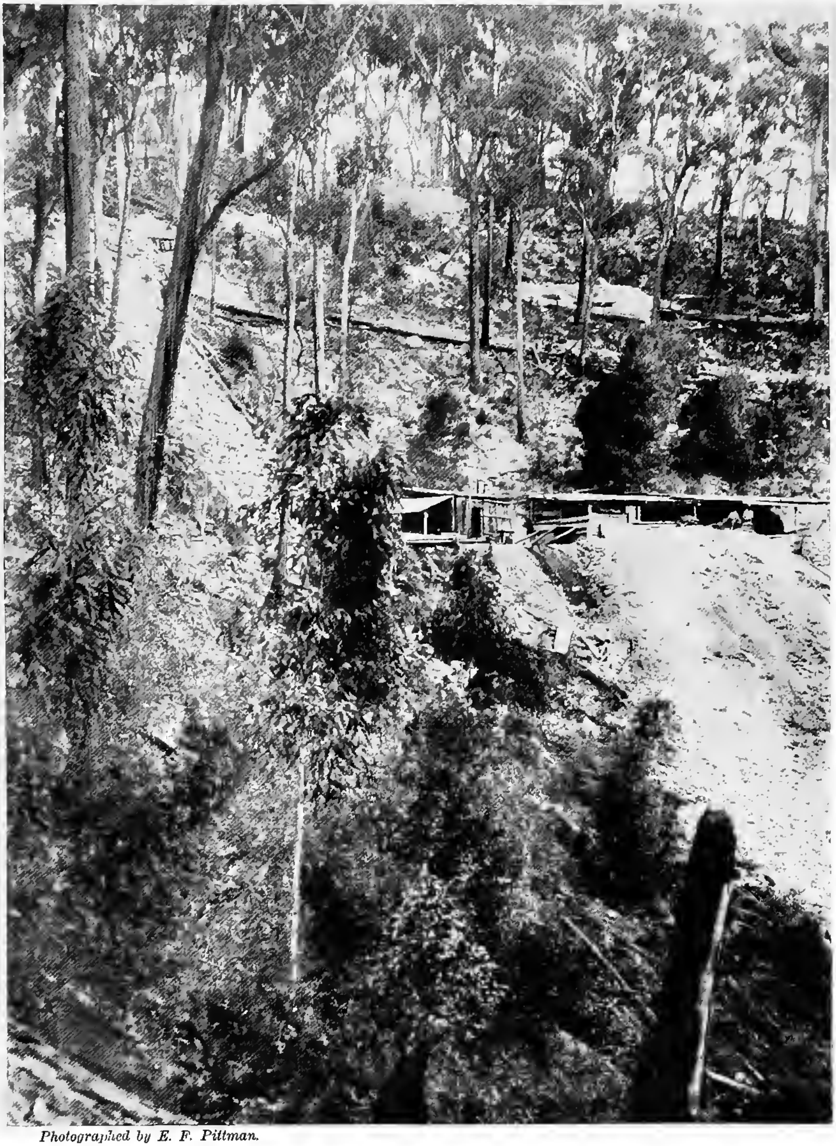
In 1891, shortly after the mines were opened, an isolated patch of extraordinarily rich ore was discovered close to the surface. It weighed three and a half tons, and was forwarded to Sydney for examination. After the parcel had been crushed and thoroughly mixed, a sample was assayed in the Laboratory of the Department of Mines, and yielded as follows :—

Metallic bismuth, 23·34 per cent.
Fine silver, at the rate of 1,108 ounces per ton.
Fine gold, at the rate of 11 dwt. 23 gr. per ton.

Further prospecting failed to reveal the source whence this apparently isolated bunch of ore was derived. One or two instances, however, of narrow but highly argentiferous veins have been discovered, and in 1893 the Company exported thirty-one tons of argentiferous bismuth ore, which yielded three and a half tons of metallic bismuth, twelve ounces of gold, and 6,107 ounces of silver. An auriferous quartz reef also occurs in proximity to the bismuth pipes, and four tons extracted from this are said to have yielded at the rate of an ounce of gold per ton ; on being followed down, however, the stone became poorer, and ceased to be payable.

The mines have been worked principally by a tunnel which has been driven in a straight course, and when pipes have been intersected by it they have been followed laterally or vertically as the case might be. From one of these pipes more than six hundred tons of ore have been extracted, and for some time past the output has been at the rate of from sixty to seventy tons per month, containing on an average about four per cent. of bismuth, the proportion varying from three to six per cent. The ore is roughly hand-picked at the mine, and is then despatched to Sydney, where it is crushed, concentrated, roasted, and then treated by the wet process.

Bismuth ores have been identified from a number of other localities in the Colony ; but, in a majority of cases, no effort has yet been made



*Photographed by E. F. Pittman.*

THE JINGERA MINERAL PROPRIETARY BISMUTH MINES, WHIPSTICK, NEAR PANBULA.

to turn them to account, and it will be sufficient to give a list of these localities in alphabetical order, and to give some brief particulars in in regard to their mode of occurrence.

*Adelong.*—Picked specimens of quartz containing iron pyrites, mispickel (arsenical pyrites), and metallic bismuth, from a reef near Adelong, were assayed in 1879 for the Department of Mines, by Mr. W. A. Dixon, F.C.S., and yielded 5·60 per cent. of bismuth.

*Captain's Flat.*— In 1888 small quantities of several bismuth ores were found at Norongo, near Captain's Flat. The minerals identified were bismuthinite (sulphide of bismuth), bismutite (carbonate of bismuth), tetradymite (telluride of bismuth), montanite (tellurate of bismuth), and telluri-bismuthic ochre. They occurred in a vein, about six inches wide, intersecting a wide gossan lode.

The following assays and analyses were made by Mr. J. C. H. Mingaye, F.C.S., in the Laboratory of the Department :—

No. 1. Clay with Carbonate of bismuth and tetradymite.

| | |
|---|---|
| Metallic bismuth ... ... ... | 16·90 per cent. |
| Tellurium ... ... ... ... | 7·04 ,, |

Fine Silver at the rate of 2 oz. 3 dwt. 13 gr. per ton.
,, Gold ,, ,, 0 ,, 3 ,, 6 ,, ,,

No. 2. Carbonate of bismuth, with tetradymite.

| | |
|---|---|
| Metallic bismuth .. ... ... | 27·88 per cent. |
| Tellurium ... ... ... ... | 10·42 ,, |

No gold or silver present.

No. 3. Carbonate of bismuth, with tetradymite.

| | |
|---|---|
| Tellurium ... ... ... ... | 19·26 per cent. |

(Bismuth not determined.)

No. 4. Tetradymite.

| | |
|---|---|
| Metallic bismuth ... ... ... ... ... | 59·66 |
| Tellurium ... ... .. ... ... ... | 33·16 |
| Selenium ... ... ... ... ... ... | ... |
| Sulphur ... ... ... ... ... ... | 4·54 |
| Iron ... ... ... ... ... ... ... | ·42 |
| Silica ... ... ... ... ... ... ... | ·40 |
| | 98·18 |

No. 5. Montanite.

| | |
|---|---|
| Bismuth oxide ($Bi_2 O_3$) ... ... ... ... | 50·68 |
| Tellurous ,, ($Te O_3$) ... ... ... ... | 27·65 |
| Iron ,, ($Fe_2 O_3$) ... ... ... ... | 14·38 |
| Water ... ... ... ... ... ... | 6·16 |
| Gangue ... ... ... ... ... ... | 1·00 |
| | 99·87 |

No. 6. Carbonate and Sulphide of bismuth.

| | |
|---|---|
| Metallic bismuth ... ... ... .. | 60·2 per cent. |

No gold or silver present.

*Cobar.*—Allusion has already been made to the presence of bismuth in the ores of the Great Cobar Copper Mine. The metal does not occur in sufficient quantity to render its extraction profitable; on the contrary it is a very objectionable element in the ore, and has, in the past, caused considerable difficulty in refining the copper. In 1878 analyses were made by Mr. W. A. Dixon, F.C.S., of a number of Cobar copper ores, and a sample of metallic copper from the Cobar Smelting Works was also analysed, with the following results:—

| | | | | | |
|---|---|---|---|---|---|
| Sample of | Copper pyrites and magnetite ... | yielded | 2·11 | per cent. | of bismuth. |
| ,, | Red oxide, copper glance, and ferric oxide | ,, | 1·47 | ,, | ,, |
| ,, | Copper pyrites, red oxide, and ferric oxide | ,, | 1·90 | ,, | ,, |
| ,, | Copper glance, with ferric oxide ... | ,, | 2·58 | ,, | ,, |
| ,, | Copper pyrites, and magnetite ... | ,, | 2·17 | ,, | ,, |
| ,, | Copper glance and red oxide ... ... | ,, | 1·18 | ,, | ,, |
| ,, | Copper glance, with malachite ... | ,, | ·95 | ,, | ,, |
| ,, | Malachite, with ferric oxide ... ... | ,, | 1·24 | ,, | ,, |
| ,, | Azurite ,, ,, ... ... | ,, | ·21 | ,, | ,, |
| ,, | Copper, smelted from these ores ... | ,, | ·419 | ,, | ,, |

*Ding Dong.*—Near the north-east corner of Portion 14, Parish of Parkes, County of Gough, close to the old Ding Dong Tin-field, and about ten miles to the east of Deepwater, a discovery of bismuth has recently been made. A quartz lode, which intersects granite close to its junction with claystone, was being worked for wolfram, but on being followed down for about twenty feet the wolfram was found to give place to native bismuth in coarse fragments. The lode also contains mispickel and molybdenite. It is possible that the bismuth may be present in payable quantity, but sufficient work has not yet been done to warrant a definite opinion on this point.

*Dundee.*—A sample consisting of quartz, with wolfram, and carbonate of bismuth, was received from Dundee in 1897, and on being assayed in the Department of Mines, yielded 1·42 per cent. of metallic bismuth.

*Elsmore.*—The surface deposits of tinstone, which were so extensively worked some years ago at Elsmore, near Inverell, were found to contain a small proportion of carbonate of bismuth.

*Emmaville.*—Several small pieces of metallic bismuth, said to have been found at a place three miles from Carpet Snake Creek, in the Emmaville District, were forwarded to the Department of Mines in 1898.

*Germanton.*—Two samples of bismuth ore, from near Germanton, were forwarded to the Department of Mines in 1890. One of these consisted of quartz, with sulphide and carbonate of bismuth, and yielded, on assay, 6·49 per cent. of the metal; the other sample consisted of quartz, with felspar, mica, oxides of tin and molybdenum, and molybdenite. It contained ·99 per cent. of metallic bismuth.

*Glen Creek.*—Professor David, in his monograph on the "Vegetable Creek Tin-mining field," records the occurrence of waterworn fragments of native bismuth near Taylor's Veins, on the Glen Creek. Two samples, said to have been found at the same locality, were forwarded to the Department of Mines in 1897. One of these, containing bismuthinite and bismutite, yielded 2·77 per cent. of metallic bismuth, while the other, which consisted chiefly of clay, with mispickel, contained ·96 per cent. of bismuth.

*Gumble.*—In the year 1886 a sample of crushed ore, said to have come from Gumble, near Molong, was received in the Department of Mines, and on being assayed was found to contain 11·76 per cent. of metallic bismuth. The granite of this district is known to contain molybdenite, and one or two lodes in the neighbourhood are said to contain small quantities of bismuth.

*Gundagai.*—At the Prince of Wales Mine, near Gundagai, a mineral containing bismuth, lead, gold, silver, and tellurium, has been found in small quantities. According to an analysis made by Mr. J. C. H. Mingaye, in the Laboratory of the Department of Mines, it has the following compositition :—

| | |
|---|---|
| Bismuth (Bi) ... ... ... ... ... ... | 27·32 |
| Lead (Pb) ... ... ... ... ... ... ... | 14·17 |
| Gold (Au) ... ... ... ... ... ... ... | 7·72 |
| Silver (Ag) ... ... ... ... ... ... ... | 2·15 |
| Tellurium (Te) ... ... ... ... ... ... | 47·12 |
| Selenium (Se) ... ... ... ... | Minute trace. |
| | 98·48 |

*Highland Home.*—In his "Geology of the Vegetable Creek Tin-mining Field," Professor David states that lumps of native bismuth, a quarter of a pound in weight, have been picked up near Burns' Reef, in Portion 3, Parish of Highland Home, County of Gough.

*Hillgrove.*—In the year 1891 three samples of bismuth ore were received in the Department of Mines from the neighbourhood of Hillgrove. These were assayed, and the following results obtained :—

| | Bismuth. | Gold. | Silver. |
|---|---|---|---|
| | per cent. | per ton. oz. dwt. gr. | per ton. oz. dwt. gr. |
| No. 1. Quartz with a little carbonate of bismuth | 12·11 | 0 4 8 | 3 18 16 |
| No. 2. do do ... | 3·37 | Trace. | 1 12 16 |
| No. 3. Washed quartz sand, with a little carbonate of bismuth and cassiterite ... | 24·42 | 0 10 21 | 11 6 11 |

In 1893 a sample from the same locality, consisting of felspathic lode stuff with galena, yielded 4·74 per cent. of metallic bismuth, together with 6 oz. 17 dwt. 3 gr. of silver, and a trace of gold.

*Hogue's Creek.*—In 1883, the late Mr. C. S. Wilkinson, F.G.S., Geological Surveyor in Charge, reported as follows upon the bismuth deposits at Hogue's Creek :—"About twelve miles north from Glen Innes, and about one mile east from the Tenterfield road, several bismuth and tin-bearing quartz veins have been discovered. These occur in a different manner from those at Kingsgate. They form irregular veins and masses of quartz, traversing a fine-grained micaceous felsitic rock, which is surrounded by altered sedimentary rocks. In one place this rock for a length of about a hundred yards and a width of fifteen yards is traversed by a network of quartz veins. A small hole has been sunk here, and the stone taken from it contains bismuth ores, tin ore (cassiterite), molybdenite, arsenical pyrites, and wolfram. In another place, about one hundred yards from that last named, a mass of hard crystalline quartz, in size, at the surface, about forty feet by twenty feet, has been opened for a few feet in depth. It contains bismuth and tin ores, together with a large quantity of wolfram. Besides this, two other small veins of quartz, yielding bismuth and tin ores, crop out close by."

"I do not consider that the vein-stuff here can be profitably worked for tin, on account of the occurrence in it of so much wolfram; but for bismuth-mining the prospects are encouraging, and the reefs should be further tested."

*Kingsgate.*—These deposits have already been described in detail.

*Molong.*—In the year 1889, a sample of quartz, containing carbonate of bismuth, was received in the Department of Mines from a locality which was described as twenty-five miles from Molong. The sample yielded by assay 13·05 per cent. of metallic bismuth, and a trace of tellurium.

*Moor Creek*, near Tamworth.—Telluride of bismuth, associated with free gold, in quartz, has been found in two localities near Tamworth, viz., at Moor Creek, and Sawpit Gully. Only small quantities of the mineral were discovered in each instance.

*Mount Allen.*—Iron ore occurs in irregular bunches at Mount Allen, about twelve miles from Mount Hope, and was for some years used as a flux for the siliceous copper ores of the New Mount Hope Copper Mine. The iron ore was subsequently found to contain gold, together with a small proportion of bismuth, and has, of late years, been worked by the Mount Allen Gold Mining Company. The first sample of this ore analysed in the Laboratory attached to the Department of Mines yielded 1·72 per cent. of bismuth oxide ($Bi_2O_3$), but a later analysis, of a sample carefully taken from all the faces of the quarry, yielded only ·25 per cent. of bismuth oxide. The presence of even this small amount of bismuth must have had a prejudicial effect upon the copper produced by the New Mount Hope Copper Mining Company, when the Mount Allen ironstone was used as a flux; but it is probable that the purchasers of the copper were more than recompensed by the gold which must have been alloyed with the copper.

*Mount Dromedary.*—Bismuth has occasionally been detected in a small lode intersecting the granite at Mount Dromedary. A sample of ore, from that locality, consisting of iron and copper pyrites, bismuthine, chalybite, etc., was analysed in the Department of Mines in 1897, and was found to contain 1·66 per cent. of metallic bismuth.

*Mount Emily.*—In 1895 a sample of weathered granite, containing bismuth ores, was received for assay in the Department of Mines, and was stated to have been found near Mount Emily, south of Quambi. It proved to contain 6·39 per cent. of metallic bismuth, together with 4 dwt. 8 gr. of gold, and 2 oz. 1 dwt. 9 gr. of silver per ton.

*Mount Gipps.*—A specimen of brown mineral, with cavities filled with carbonate of bismuth, was received from Mount Gipps in the year 1884, and, on being assayed, was found to contain 14·55 per cent. of metallic bismuth.

*Mount Mitchell.*—The first bismuth ores from Mount Mitchell, near Glencoe (Glen Innes District), of which there is any record, were forwarded to the Department of Mines in 1888. They were found to contain as follows:—

| | Description of Ore. | Metallic bismuth. | Gold. | Silver. |
|---|---|---|---|---|
| | | per cent. | oz. dwt. gr. | oz. dwt. gr. |
| No. 1 | Quartz, with native bismuth, and oxide and carbonate of bismuth (concentrated). | 62·0 | 4 11 10 | 1 1 16 |
| No. 2 | Quartz, with carbonate of bismuth ...... | 5·91 | nil. | nil. |
| No. 3 | ditto ditto .... | 1·44 | trace | ,, |
| No. 4 | Oxide and carbonate of bismuth (concentrated). | 66·2 | nil. | ,, |

In 1889 the deposits from which these samples had been taken were examined by Mr. William Anderson, Geological Surveyor, from whose report the following extract is taken:—"The position of these bismuth-bearing veins is in the north-west corner of the Parish of Coventry, County of Clarke, and is about a mile to the south-east of Mount Mitchell. The bismuth ores occur distributed in small irregular patches through a series of quartz veins, averaging from half an inch up to four inches in thickness. The quartz is clear and translucent, and towards the centre of some of the veins is crystalline, the pyramidal apices of the crystals from opposite sides of the veins interlocking in the centre."

"The contained bismuth ore is in the form of oxide, sulphide, and carbonate of bismuth, which in many cases are found to cover a central nucleus of metallic bismuth. The veins traverse a ternary granite, whose general texture and mineral constituents vary very much. Their strike is south-west, and north-east, and they pass downwards in a nearly vertical direction, with a slight inclination to each other, as if they would unite at a lower depth. Their outcrop can be traced for a considerable distance along the surface, and small quantities of bismuth can be washed from the soil in the immediate neighbourbood of the outcrop. The veins contain a fair percentage of free gold. Little or no work has yet been done in opening up or proving the extent of the bismuth-bearing veins. A couple of holes have been sunk, averaging about ten feet deep. The mode of occurrence of the bismuth ores here differs slightly from that at the Kingsgate Mines, in that, at the latter place, they occur in pipe-veins near the junction of the granite with the slate, while here they are found in quartz veins traversing the mass of the granite. Of two assays made of the quartz, one returned 5 per cent. of metallic bismuth, with traces of gold, and the other showed traces of metallic bismuth."

"The only positions, in granite, in which large and permanent mineral-bearing lodes or reefs may be expected to be found are along the lines of junction of an intrusive granite mass or dyke, with sedimentary or volcanic rocks, and within the area occupied by the granite wherever there is evidence of the presence of a line of weakness, such as a well-defined fault. When veins or reefs occur in granite where there is no evidence of faulting, as in the present case, they cannot be expected to be of any great size or permanency, because such veins doubtless occupy small fissures, which have been formed either during the cooling and crystallisation of the granite, or subsequently by mechanical strain, which had not been sufficiently powerful to produce extensive faulting. Consequently it will no doubt be found, on proving these veins, that they are, more or less, lenticular in shape, thickening and thinning out, and running together in a very irregular manner, although probably on the same vertical line. They do not present, so far as one can judge from their present development, the same prospects of such large quantities of bismuth ore being obtained as in the case of the pipe-veins of Kingsgate."

*Murrumbateman.*—In September, 1899, a sample of bismuth-bearing weathered granite was received in the Department of Mines from Messrs. Mair and Watson's Claim at Murrumbateman. It yielded on assay :—

| | | | | | |
|---|---|---|---|---|---|
| Gold ... | ... 4 oz. | 4 dwt. | 22 gr. | per ton. |
| Silver ... | ... | 16 ,, | 8 ,, | ,, |
| Bismuth | ... 15·63 per cent. | | | |

*Nanima.*—Bismuth ores occur in auriferous quartz veins at Nanima, six miles east of Murrumbateman, near Yass. A sample collected by one of the officers of the Geological Survey was assayed in the Department of Mines, and yielded at the rate of 6·37 per cent. of bismuth, and 1 oz. 7 dwt. of gold per ton. More recently carbonate of bismuth has been saved, by concentration, from the auriferous quartz at Terry's Estate, Nanima, in the proportion of about one hundredweight to ten tons of stone. A sample of these concentrates is now in the Geological Museum.

*Nimitybelle.*—In 1888 bismuth ores were found near Nimitybelle in the Southern District. A sample, consisting of quartz with sulphide of bismuth, was forwarded to the Department of Mines, and was found to contain 3·67 per cent. of the metal. Subsequently several other samples were received from the same locality, and the richest of these contained 8·81 per cent. of metallic bismuth.

*Oban.*—In 1889 two samples of bismuth ore, said to have been obtained at Oban, were assayed in the Department of Mines. One of these consisted of native bismuth, with some carbonate and oxide. It yielded 75·60 per cent. of the metal; the other, which consisted of friable earthy carbonate, yielded 10·04 per cent. of metallic bismuth. In 1891 a third sample, composed of quartz and felspathic gangue, with molybdenite, was found to contain 1·45 per cent. of bismuth, together with 4 dwt. 8 gr. of gold, and 2 dwt. 4 gr. of silver per ton.

*Orange.*—In 1882 a specimen of ore which was received in the Department of Mines for assay, and which was stated to have been found near Orange, was found to contain 5·4 per cent. of bismuth; copper, a trace; silver, at the rate of 4 oz. 2 dwt. per ton; and gold, a trace.

*Parkes*, Parish of, County of Gough. (*Vide Ding Dong*).

*Pheasant Creek.*—Quite recently deposits of bismuth have been found at Pheasant Creek, in the Parish of Moogem, County of Clive, about forty miles to the north-east of Glen Innes. The deposits are, in every respect, similar to those which have already been described as occurring at Kingsgate, more than thirty miles distant. They consist of more or less cylindrical pipe-veins intersecting granite country in proximity to its junction with Carboniferous claystones. The filling of the pipes consists of quartz, and many fine specimens of large hexagonal crystals occur in vughs; much of the quartz is of the smoky variety known as cairngorm. The minerals disseminated through the gangue are wolfram, native bismuth, sulphide of bismuth, and molybdenite, while near the surface carbonate of bismuth and bismuth ochre are met with.

Only one of these pipes has, so far, been opened, and a shaft has been sunk upon it to a depth of about twenty feet by Mr. John Low, the discoverer. The mineral sought for was wolfram, but after the excavation had reached a few feet in depth, native bismuth was met with in solid masses, the largest of which weighed three and a half pounds.

It is very probable that many of these bismuth-bearing pipes will be found in the vicinity, and there is every reason to expect that they will be similar in ore values to those which occur in the neighbourhood of Kingsgate.

*Pye's Creek.*—In his work on the Vegetable Creek Tin-mining Field, Professor David states (in 1885) that "in one of the veins on Pye's Creek bismuth is reported to have been recently discovered in some quantity." In the same year, three samples were received in the Department of Mines from this locality, and on being assayed were found to contain as follows :—

| | Bismuth. | Silver. |
|---|---|---|
| | per cent. | per ton. oz. dwt. |
| No. 1 ...Ferruginous quartz and metallic bismuth from 40-acre block adjoining Hamilton and Party's lease, Pye's Creek. | 66·8 | 35 8½ |
| No. 2 ...Ferruginous quartz and metallic bismuth, with carbonate of copper ; from same locality. | 3·9 | 200 18 |
| No. 3 ...Ferruginous sand and galena, and a little carbonate of copper ; from same locality. | 13·3 | 166 12 |

*Silent Grove*, Vegetable Creek District.—Professor David states that "Bismuth has been found native, and as carbonate and sulphide, associated with tinstone and quartz, in Portion 15, Parish of Silent Grove. The total width of the vein is about one foot, and its strike 15° south of east and north of west, with a northerly dip. The bismuth is distributed through the quartz chiefly in acicular crystals, and lies next to the foot wall; the thickness of the bismuth-bearing part of the vein is four inches."

*Slippery Creek*, near Tarana.—Mr. E. C. Whittell, of the Department of Mines, found telluride of bismuth associated with free gold, in quartz, in Mitchell and Party's claim, near Slippery Creek, in 1897.

*Solferino.*—In 1890 two samples of bismuth ore were received from Ewingar, near Solferino, and were assayed with the following results :—

| | Description of Ore. | Bismuth. | Gold. | Silver. |
|---|---|---|---|---|
| | | per cent. | | oz. dwt. gr. |
| No. 1 | Carbonate of bismuth in brown iron ore | 69·95 | nil. | 2 5 17 |
| No. 2 | Brown iron ore, with a little oxide of bismuth. | 0·63 | trace. | trace. |

*Sunny Corner.*—Two samples of ore from the Sunny Corner Mine, collected by the late Mr. C. S. Wilkinson, F.G.S., in 1886, were analysed in the Department of Mines, and were found to contain a small proportion of bismuth. In one of these samples only a trace of bismuth was detected, while in the other ·88 per cent. of the metal was obtained.

*Tarana.*—A specimen of telluride of bismuth was received from Mitchell's Claim, Hazlegrove, Tarana, in 1898, and was analysed in the Department. It yielded the following results:—

| | |
|---|---|
| Bismuth ... ... ... .. .... | 70·82 |
| Tellurium ... ... ... ... ... | 19·59 |
| Sulphur ... ... ... ... ... | 4·69 |
| Gangue ... ... ... ... ... | ·06 |

No selenium, gold or silver detected.

*Tent Hill.*—In 1897 a sample of decomposed micaceous rock, said to have been obtained at Tent Hill, was received in the Department of Mines for assay, and was found to contain 3·46 per cent. of bismuth.

*Tenterfield.*—In 1879 two samples of bismuth ore were received from Tenterfield, and were assayed for the Department of Mines by Mr. W. A. Dixon, F.C.S. The first consisted of a yellow friable ochreous mass of carbonate and oxide of bismuth, with quartz and molybdic oxide, and contained 43·29 per cent. of metallic bismuth. The second sample was described as "quartz, with metallic bismuth, carbonate of bismuth, molybdic oxide, and sulphide, from a reef four feet wide;" it was found to contain at the rate of 60·09 per cent. of bismuth, 1 oz. 4 dwt. 10 gr. of gold, and 8 dwt. 10 gr. of silver per ton.

In 1889 another sample, from the same locality, yielded 2·72 per cent. of bismuth; and in 1890 a specimen of compact felsite, with oxide of tin, magnetic iron, and a little carbonate of bismuth, was found to contain 1·50 per cent. of the metal. Bismuth ore has also been received from a locality five miles south of Tenterfield.

*Tingha.*—In 1879 two samples from Tingha were assayed by Mr. W. A. Dixon, F.C.S., for the Department of Mines; one of these consisted of waterworn nodules of carbonate and oxide of bismuth, and yielded at the rate of 60·43 per cent. of the metal; the other, which was similar in character, but associated with talc and ferric oxide, contained 62·75 per cent. of bismuth

In 1887, a specimen of lodestuff from Tingha yielded, by assay, ·35 per cent. of metallic bismuth, and a sample of concentrates from 15 lb. of rubble, containing native bismuth and oxide of bismuth, yielded at the rate of 76·62 per cent. of the metal.

In 1888 two more samples from the same locality were received for assay. One of these consisted of ferruginous quartz, with oxide, carbonate, and native bismuth; it yielded at the rate of 5·36 per cent. of bismuth, together with 13 dwt. 6 gr. of gold per ton, and a trace of silver. The other sample, ferruginous quartz, contained 1·06 per cent. of metallic bismuth, but no gold.

*Uralla.*—In 1897, telluride of bismuth, associated with free gold, was identified by Mr. G. W. Card, A.R.S.M., in a specimen of white quartz from Kentucky Run, near Uralla.

*Wee Jasper.*—A specimen of quartz containing bismuth ores has been received in the Department of Mines from the neighbourhood of Wee Jasper.

*Whipstick.—Vide* Jingera Mineral Proprietary Mines, already described in detail.

PRODUCTION OF BISMUTH.

| Year. | Quantity. | Value. |
|---|---|---|
| To end of | Tons. | £ |
| 1880 ... ... ... | 14·80 | 2,852 |
| 1881 ... ... ... | 12·50 | 2,729 |
| 1882 ... ... ... | 2·70 | 162 |
| 1883 ... ... ... | 3·70 | 650 |
| 1884 ... ... ... | 14·38 | 2,770 |
| 1885 ... ... ... | 14·17 | 3,700 |
| 1886 ... ... ... | 20·90 | 3,870 |
| 1887 ... ... ... | 36·55 | 6,695 |
| 1888 ... ... ... | 18·08 | 3,911 |
| 1889 ... ... ... | 42·50 | 11,349 |
| 1890 ... ... ... | 2·10 | 306 |
| 1891 ... ... ... | ·40 | 500 |
| 1892 ... ... ... | 14·25 | 1,080 |
| 1893 ... ... ... | 6·00 | 402 |
| 1894 ... ... ... | 9·00 | 480 |
| 1895 ... ... ... | 2·45 | 164 |
| 1896 ... ... ... | 41·00 | 490 |
| 1897 ... ... ... | 3·10 | 800 |
| 1898 ... ... ... | 29·35 | 4,615 |
| 1899 ... ... ... | 15·55 | 3,355 |
| Totals... ... | 303·48 | 50,880 |

# MERCURY.

## *Ores of Mercury.*

*Native Mercury.*—Occurs in small fluid globules scattered through its gangue ; composition, pure mercury (Hg.) with sometimes a little silver ; specific gravity, 13·596 ; lustre metallic, very brilliant ; colour, tin white ; opaque.

*Cinnabar.*—Composition, mercuric sulphide (Hg. S.) contains 86·2 per cent. of mercury ; usually impure from the admixture of clay, iron oxide, &c. ; occurs in rhombohedral crystals, in crystalline incrustrations, massive, and sometimes as an earthy coating ; hardness, 2–2·5 ; specific gravity, 8–8·2 ; lustre adamantine, inclining to metallic, and sometimes to dull ; colour cochineal-red, brownish-red, and lead-gray ; streak scarlet ; transparent to opaque. Frequently accompanied by globules of native mercury. Cinnabar is the principal source of the World's supply of quicksilver.

Ores of mercury have not hitherto been profitably worked in New South Wales, although deposits of cinnabar have for some years been known to occur in several districts. Large quantities of mercury, however, are imported annually for use in the extraction of gold from its ores by amalgamation, and in view of the importance of having a supply of the metal available in the Colony, the Government have endeavoured to stimulate its production by the offer of a reward of £500 for the first 50,000 lb. of mercury extracted from New South Wales ore.

## *Uses of Mercury.*

The chief uses for mercury are in the reduction of gold and silver ores by amalgamation, and the manufacture of vermilion, or artificial sulphide of mercury, which is a valuable pigment. The silver amalgamation mills of the United States are stated to use from ·5 to 2·5 lb. of mercury per ton of ore treated, while the gold-mills use from ·01 to ·06 lb. per ton. The total production of vermilion in the United States amounts to about 240,000 lb. per annum, valued at nearly £24,000. The amount of mercury contained in this product is 204,000 lb., representing about one-tenth of the total amount of the metal produced in the country.

Vermilion is made by fusing a calculated mixture of mercury and sulphur at a moderate heat, the resulting powder being of a cochineal-red colour, which yields, when pulverised, a scarlet powder. The beauty of colour of this powder depends upon the purity of the materials used in its preparation, and upon the care taken to avoid an excess of sulphur. Vermilion may also be prepared by precipitating a solution of corrosive sublimate, in ammonia, with a solution of sulphur, in ammonium sulphide. The manufacture of vermilion has fallen off of late years on account of the competition of cheaper pigments which have taken its place. The most important of these is "orange mineral" (red lead), which is toned up to the proper colour by means of eosine, one of the aniline dyes. These imitation vermilions are now used for almost all the commoner purposes, like waggon-painting, &c. They are inferior to the true mercury vermilion from the fact that they fade on exposure, but in waggon-painting and like purposes they do well enough, lasting so long as they are protected by a coat of varnish. True vermilion is sometimes adulterated with the imitation, but this can easily be detected by heating a sample, when the sulphide of mercury will be volatilised, while foreign substances remain behind. Mercury vermilion is now chiefly employed for red colours in painting, lithographing, etc.

*Price of Mercury.*—The following information in regard to the London market is taken from Rothwell's "Mineral Industry":—

| Year. | Price per flask (76·5 lb.) | |
|---|---|---|
| | Lowest. | Highest. |
| | £ s. d. | £ s. d. |
| 1884 ... ... ... | 5 1 6 | 6 15 0 |
| 1885 .. ... ... | 5 10 0 | 6 17 6 |
| 1886 ... .. ... | 5 13 0 | 7 10 0 |
| 1887 ... ... ... | 6 10 0 | 11 15 0 |
| 1888 ... ... ... | 6 15 0 | 10 10 0 |
| 1889 ... ... ... | 7 7 6 | 9 15 0 |
| 1890 ... ... ... | 8 17 6 | 10 7 6 |
| 1891 ... ... ... | 7 5 0 | 9 0 0 |
| 1892 ... ... ... | 6 1 0 | 7 15 0 |
| 1893 ... . .. | 6 2 6 | 6 17 6 |
| 1894 ... ... ... | 5 10 0 | 6 15 0 |
| 1895 ... ... ... | 6 7 6 | 7 7 6 |
| 1896 ... ... ... | 6 7 6 | 7 7 6 |

*Metallurgy of Mercury.*—According to Schnabel and Louis*, there are two methods of extracting mercury from cinnabar, viz. (1) by heating cinnabar in the air, and (2) by heating cinnabar with lime and iron, air being excluded.

"As regards the choice of the most suitable process, the preference should, as a general rule, both for economic and for hygienic reasons, be given to the extraction of mercury by heating cinnabar in the air, rather than by the employment of lime or iron. Heating cinnabar in

* Handbook of Metallurgy, vol. II, p. 260.

the air is a process that may be carried out either in shaft furnaces, reverberatory, or muffle furnaces. When shaft and reverberatory furnaces are used, large quantities of ore can be treated with a comparatively small consumption of fuel and labour; the process also can be so arranged that the workmen are not troubled by the mercurial vapours. On the other hand, the process is open to the objection that the mercurial vapours are diluted by sulphur dioxide, oxygen and nitrogen; and in the case of shaft and reverberatory furnaces, also by the products of combustion, and that the complete condensation of the mercury is therefore rather difficult, consequent losses of metal through incomplete condensation being accordingly unavoidable. The extraction of mercury by heating cinnabar with lime or iron must be performed in retorts. Concentrated mercurial vapours, which can readily be condensed, are thus obtained; but the process is open to the objection that the ores must first be crushed, that only small quantities can be treated, that the retorts last for only a comparatively short time, that the operation is attended with high costs for fuel and labour, and that the workmen are affected by the mercurial fumes when the retorts are emptied out. Although the output of mercury is somewhat higher than in the first-named process, it is nevertheless inferior to it on account of the high working costs, so that it is absolutely unsuitable for poor ores. The chief objection, that the workmen are attacked by the mercurial vapours, is of such paramount importance that the process should really not be carried on at all. It has therefore been given up at the majority of works, and has been replaced by the first-named process; its use can only be justified for the treatment of merely small quantities of ores containing a very high percentage of mercury."

The first record of the occurrence of mercury in New South Wales is in a paper contributed by the late Rev. W. B. Clarke to the *Sydney Magazine of Science and Art*, in 1859. He states therein that about the year 1843 he received his first sample of native quicksilver in yellow soil from near Carwell Creek, on the Cudgegong River. Mr. Clarke was doubtful about the occurrence, and considered that the mercury might have been accidentally dropped there; however, as cinnabar was afterwards found in this locality, the original discovery was probably genuine.

Stutchbury also mentions the discovery of native mercury in Mookerwa Creek, and the Great Waterhole, at Ophir, in the year 1851.

In 1870, the Rev. W. B. Clarke wrote as follows, in a volume entitled *The Industrial Progress of New South Wales*:—"Two deposits of cinnabar have been found on the banks of the Cudgegong River, four or five miles from the township of the same name. The ore was not found in a regular lode but was traced in small veins of flood débris, highly impregnated with the red sulphuret of mercury, and lying vertically in the ordinary alluvium. It has been worked to some extent, but the quantity procurable was not considered sufficient to justify the company in carrying on an extensive establishment. Attempts are being made to follow up the track of the débris in the hope of striking the real lode. The writer recently saw unmistakable traces of the red sulphuret of mercury in the workings at a small diggings in the neighbourhood of Trunkey Creek."

Again, in 1875, Mr. Clarke wrote: "Some years ago I reported on the occurrence of mercury in this Colony; but my expectation of the discovery of a lode of cinnabar has been disappointed. The cinnabar occurs on the Cudgegong in drift lumps and pebbles, and is probably the result of springs, as in California. In New Zealand, and in the neighbourhood of the Clarke River, North Queensland, the same ore occurs in a similar way."

In 1884, the late Mr. C. S. Wilkinson, Geological Surveyor in Charge, examined and reported upon the Cudgegong River cinnabar deposit. He found that it was situated about five miles west from the town of Rylstone at a point where the Cudgegong River makes a sudden bend from the south-east to the south-west. Across the point formed by this bend occurs a patch of old Tertiary drift, about half a mile long and from five to ten chains wide. The drift is composed of very waterworn quartz pebbles, and red ferruginous sandy clay, with irregular masses of brown ironstone. This deposit represents a portion of the old bed of a stream which, in tertiary times, flowed down the Cudgegong Valley, the present river channel having been subsequently eroded. The ranges on either side of the river rise to a height of about 250 feet, and are composed of porphyry and Devonian sandstones, shales, and limestones. The old drift once occupied a position in the valley at least 120 feet higher than the present river bed, but it has since been extensively removed by denudation, and now forms a gravelly spur, sloping gradually down to the river. At the time of Mr. Wilkinson's inspection, a prospecting shaft, which had been sunk to a depth of 203 feet, had been abandoned. In this shaft cinnabar was found, more or less, through the drift from the surface to a depth of fifty feet on a false bottom, and the deposit without cinnabar continued to a depth of 117 feet, when the true bed rock of Devonian schist was met with; but at 170 feet, when in black schists, a vein, four inches thick, which dipped to the south-west, and contained a little cinnabar, was met with. Near this shaft there was another which bottomed at a depth of sixty-eight feet; a false bottom was met at forty feet, and cinnabar was found above this. The cinnabar was found in sharp angular pieces, varying from several pounds in weight down to the size of fine dust; sometimes the surfaces of the pieces were somewhat rounded, but it was considered questionable whether this was due to attrition. Some of the drift from close to the surface was washed, and gave fair prospects of both cinnabar and fine gold.

Perhaps the most important feature connected with the occurrence of the ore, according to Mr. Wilkinson, was that the solid cinnabar was sometimes seen to gradually merge into or impregnate the clay or drift of the deposit in which it was found ; and this was regarded as direct evidence that it had not been drifted by running water, like the water-worn pebbles and other material forming the old Tertiary lead, but had probably been derived from thermal water, which issued from the underlying Devonian rocks, and permeated the Tertiary deposit. It was inferred, therefore, that the deposit of cinnabar must be more or less local.

It was stated that the average yield from the drift had been from ½ to 1 dwt. of gold to the load, with a variable quantity of cinnabar. The gold was fine and scaly, and some of it was coated with amalgam, pointing to the occurrence of free mercury in the drift.

Since the publication of Mr. Wilkinson's report the quantity of cinnabar obtained from these deposits has not been important.

*Deposit of Cinnabar at Spring Creek, near Bingera.*—Fragments of cinnabar were discovered many years ago by miners prospecting for alluvial gold at Spring Creek, about three miles south-east of Bingera, but it was not until the year 1890 that the matrix, from which these fragments had been derived, was found. Mr. T. W. E. David, Geological Surveyor, examined and reported upon this deposit in 1891. He found that the cinnabar was disseminated through serpentine resulting from the alteration of an intrusive ultra-basic rock. The dyke of serpentine had intruded beds of claystone and limestone, which are probably of Siluro-Devonian age. The claystones showed distinct contact metamorphism, having been converted into yellow jasperoid rocks in proximity to the serpentine; and where limestone was in contact with the serpentine a compound rock had been formed from the combination of the two, they having been completely fused together along their line of junction. Segregated masses of chrome iron were observed at intervals in the serpentine, and the cinnabar occurred in the dyke mass along its line of contact with the sediments. Three samples of the dyke-stone were assayed in the Laboratory of the Department of Mines, and yielded as follow :—

| | | | | | |
|---|---|---|---|---|---|
| No. 1 | contained | ·63 | per cent. | of metallic | mercury. |
| No. 2 | ,, | ·65 | ,, | ,, | ,, |
| No. 3 | ,, | ·01 | ,, | ,, | ,, |

No. 3 assay was made from a sample of ten pounds weight, carefully selected by Mr. David from the bottom of a 25-foot shaft, and was probably fairly representative of the deposit. Assays Nos. 1 and 2 were from picked samples.

There was evidence of a secondary deposition of cinnabar on a small scale, in the fact that here and there, in that portion of the dyke which carried cinnabar, the mineral occurred in films or narrow veins filling irregular cracks in the dykestone. These veins were observed to be not more than about one-tenth of an inch thick, and were of comparatively rare occurrence.

The Government granted aid from the Prospecting Vote to test this deposit by sinking a shaft to a depth of 100 feet, for although the ore near the surface was not payable, it was considered probable that it might improve at a depth. The shaft was accordingly continued for seventy-eight feet, at which depth coarse cinnabar was showing, but unfortunately a supply of water was struck which could not be dealt with without special appliances, and as the owner of the mine was unwilling to incur the expense of obtaining these, mining operations were stopped for some time. An attempt is now being made, however, to further prospect the mine.

*Deposit of Cinnabar at Horseshoe Bend, Clarence River.*—This deposit, which was discovered in 1891, is situated about three-and-a-half miles south-east of Lionsville. It was examined by Mr. T. W. E. David, Geological Surveyor, who described it as a dyke, twelve feet wide, of felspathic rock allied to serpentine, containing cinnabar distributed irregularly through it in spots and minute veins. This dyke intersects the granite of the district, and is likely, in Mr. David's opinion, to be permanent to a depth. Here again aid was granted from the Prospecting Vote to sink a shaft 100 feet, and to put in a drive across the dyke, but the owner of the claim was unwilling to bear half the cost of the work, and it was consequently never proceeded with.

*Deposit of Cinnabar near Lionsville, Clarence River.*—Mr. J. E. Carne, Geological Surveyor, has examined and reported upon a deposit of cinnabar situated about five chains from the south-west corner of Portion 15, Parish of Ewengar, County of Drake, and about three quarters of a mile west of the Clarence River. The country in the vicinity of the deposit consists of hornblende granite which has been intruded by a dyke of fine-grained quartz-diorite. There are four distinct ore veins, the most important of which, according to Mr. Carne, being along the junction of the diorite dyke with the hornblendic granite. "Here the largest defined ore body is exposed, which, from its mode of occurrence is likely to prove permanent to great depths. An interesting feature is the impregnation of both contact rocks with cinnabar, extending to at least the full width of the shaft. From the field and microscopic evidence it would appear that solfataric mineral solutions, containing mercury and a little antimony sulphide, followed the diorite intrusion along contraction fissures, permeating both dyke and country for a distance as yet unproved." The cinnabar is associated as a general rule with quartz and calcite, but in what is known as Miller and Pollard's Shaft, at a depth of seventy-four feet, globules of native mercury were visible in the cinnabar, and the latter was associated with blue and green carbonates of copper. In one place Mr. Carne found that the ore body presented a horizontally banded appearance owing to the arrangement of finely-divided particles of cinnabar. This ore body was about seven feet thick and carried about one half per cent. of mercury throughout.

Individual veins of cinnabar were found to vary in thickness from several inches down to mere threads. A specimen of picked ore from one of the thickest of these veins yielded as follows by assay :—

| | |
|---|---|
| Metallic mercury ... | 60·70 per cent. |
| Silver ... ... .. | 6 oz. 10 dwt. 15 grains per ton. |
| Gold ... ... ... | A trace (under 2 dwt. per ton). |

The following results were obtained from samples selected by Mr. Carne from a band of decomposed lodestuff about seven feet thick.

No. 1. "Picked" from pink layers from one to two inches thick in a vertical section of 3 ft. 6 in. :—

| | |
|---|---|
| Metallic mercury ... ... | ·48 per cent. |
| Copper ... ... ... | a minute trace. |
| Neither gold nor silver. | |

No. 2. An average sample taken from the full thickness of 3 ft. 6 in. :—

| | |
|---|---|
| Metallic mercury ... ... | ·50 per cent. |
| Copper ... ... ... | a minute trace. |
| Neither gold nor silver. | |

A sample of undecomposed lodestuff, having a pink tint owing to included cinnabar, was assayed with the following result :—

| | |
|---|---|
| Metallic mercury ... ... | 1·58 per cent. |
| Copper ... ... ... | a minute trace. |
| Neither gold nor silver. | |

A tin-white material, which weathers to a bronze colour, and contains mercury, copper, antimony, and sulphur, was found with the cinnabar. The two minerals were too intimately associated to allow of their perfect separation, but a complete analysis was made by Mr. Mingaye, F.C.S., of the mixed ore, with the following results :—

| | | | |
|---|---|---|---|
| Metallic mercury ... | 43·68 | Magnesia ... ... | ·21 |
| ,, copper ... | 6·87 | Gangue ... | 30·46 |
| ,, antimony ... | 4·44 | Sulphur ... ... | 11·46 |
| ,, arsenic ... | Trace | Carbonic Acid ... | ·44 |
| ,, iron ... ... | .45 | Moisture at 100° C .. | ·25 |
| Alumina ... ... | Trace | | |
| Lime ... ... ... | 1·26 | | 99·52 |

Fine silver at the rate of 9 oz. 6 dwt. 4 gr. per ton.
Fine gold, a trace.

Mr. Carne is of opinion that the success of the mine, which is now the property of the Great Australian Quicksilver Mining Company, (Limited), will depend upon the value and workableness of the lower-grade deposits, which alone offer sufficient promise of occurring in quantity. The following quotation is from his latest report on these deposits*:—

"Whilst the quantity of cinnabar-bearing material in sight has been increased by further prospecting, the grade has not correspondingly

* Mineral Resources No. 7. "Mercury or Quicksilver in New South Wales," by J. E. Carne, F.G.S.

improved. The line G to F will probably yield a workable quantity of ore yielding from 0·5 to 1 per cent. of mercury. From the Main Shaft, D, and Doctor's Shaft, F, lesser quantities of similar grade will be obtainable. From B no ore approaching this grade is yet obtainable; whatever its prospects in depth, it cannot yet be taken into account. The question confronting the newly-formed company now is—can ore of the above grade be profitably worked under local conditions? Certainly even lower grades are successfully operated on in Europe and Russia; but circumstances alter cases, and it is more than doubtful if the Yulgilbah deposits could be attacked on a commercial scale as they now appear. On the other hand, there is every reasonable inducement, as there is every need, for an adequate test to effectually decide their workableness or otherwise."

*Tenterfield.*—In 1890 a specimen containing cinnabar, said to have been obtained from near Tenterfield, was received in the Department of Mines. The specimen consisted of felstone, with veins of crystalline quartz and with cinnabar and pyrites well disseminated through the felstone. It yielded on assay 1·99 per cent. of mercury.

The following is a complete list of the localities in New South Wales in which minerals containing mercury have been found:—

| Locality. | Geological Formation. |
|---|---|
| Bingara, Spring Creek, near, County Murchison | Serpentine and clay slate. |
| Boorook, Clifton Silver Mine, County Buller | Carboniferous claystone. |
| Broken Hill, Broken Hill Lode, County Yancowinna | Gneiss and quartzites, age uncertain. |
| ,, Australian Broken Hill Consols, County Yancowinna | Amphibolites. |
| Corinda Creek, five miles westerly from Woolgoolga, North Coast, County Raleigh (?) | Ferruginous quartz. |
| Crow Mountain, near Barraba, County Darling | Carboniferous claystone. |
| Cudgegong River, six miles below Rylstone, County Roxburgh | Slates, sandstones, and limestones. |
| Dungog (Calton Hill), County Durham | ? |
| Grove Creek, near Trunkey, County Georgiana | Alluvial Drift (Pleistocene). |
| Horseshoe Bend, Clarence River, County Drake | Felspathic dyke in granite. |
| Mookerwa, County Westmoreland | (Amalgam.) |
| Moruya, County Dampier | ? |
| Mudgee (? Cudgegong), County Phillip | Sandy schist. |
| Ophir, County Bathurst | (Amalgam.) |
| Scone, near, County Brisbane | ? |
| Sunny Corner, County Roxburgh | ? |
| Tenterfield, near, County Clive (?) | Felstone and quartz. |
| Yulgilbar, Clarence River, County Drake | Hornblendic granite with dykes of diorite. |

# CHROMIUM.

Chromic iron ore occurs in a number of localities in New South Wales, and is always found in serpentine rocks in the form of bunches or irregular masses.

The mineral chromite, or chrome iron ore, has an iron-black or brownish-black colour, and, when pure, contains 32 per cent. protoxide of iron. and 68 per cent. of sesquioxide of chromium. Its composition is therefore represented by the symbol FeO, $Cr_2O_3$. Its hardness is 5·5, and it has a specific gravity of from 4·32 to 4·56. It is a brittle mineral, breaks with an uneven fracture, and is sometimes magnetic.

According to Vogt, the deposits of chromite are basic magmatic segregations from peridotite, and occur as irregular lenticular masses in peridotite or in serpentine which has resulted from the alteration of that rock. The similar mode of occurrence of chromite all the world over appears to support this view, viz., that it separated in irregular bunches (segregations) from the original intrusive rock, before the latter had become thoroughly consolidated.

Surface outcrops of chromite therefore are liable to be very misleading, since there is no certainty as to the continuance of the deposits in depth, and in a majority of instances the bunches or pockets are found to be of very small dimensions. On the other hand, however, they are very easily mined owing to the favourable nature of the country rock (serpentine). Although no extensive alluvial deposits of chrome iron ore have as yet been discovered in this Colony, it is probable that they do occur here, for the mineral exists as minute grains in all serpentines, and the denudation of these rocks, as well as of the larger bunches of ore, must result in the formation of detrital deposits, which only await the operations of the prospector.

The recognised standard or grade for marketable chrome iron ore is 50 per cent. of sesquioxide of chromium; but, unfortunately, much of the mineral occurring in New South Wales contains less than this amount; it is certain, therefore, that the future of the chrome-mining industry must depend, to a large extent, upon the assistance of concentrating or ore-dressing machinery, as has been the case in other parts of the world. One of the chrome-dressing works now in active operation in California is equipped as follows, according to Rothwell's "Mineral Industry":—Rockbreaker, six-foot Huntingdon mill, and four Woodbury vanners with corrugated belts, together with settling tanks, drying floors, and the usual drying machinery, &c. The plant, which is capable of turning out from twenty to twenty-five tons of dry concentrates per twenty-four hours, cost about £2,400. The process is carried out as follows:—The ore is crushed by the breaker and the Huntingdon mill so as to pass a 40-mesh sieve. The pulp is separated on the Woodbury vanners. The concentrates are collected in settling tanks, whence they are removed to the drying floors, and finally packed for shipment in strong jute bags. Wood is used for fuel. The crude ore costs about 28s. per ton, for best grades, delivered at the mill. In a month's run 700 short tons of 50 per cent. concentrates were obtained, which yielded a profit of 12s. 6d. per ton, and 4s. 2d. for each unit above 50 per cent.

The following analyses show the composition of the crude ore and the concentrates respectively:—

| | | |
|---|---|---|
| Sesquioxide of chromium ... ... | 43·70 | 52·86 |
| Protoxide of iron ... ... ... | 14·80 | 15·45 |
| Alumina ... ... ... ... | 15·96 | 11·59 |
| Magnesia ... ... ... ... | 16·49 | 16·26 |
| Silica ... ... ... ... ... | 7·96 | 3·00 |
| Lime ... ... ... ... ... | ·66 | ·76 |
| Water ... ... ... ... ... | ·49 | ·10 |
| | 100·06 | 100·02 |

*Uses of chrome iron ore.*—The following extracts are from "The Mineral Industry":—"Chrome iron ore is used in the arts for the manufacture of potassium and sodium bichromates, for the preparation of basic furnace hearths, and for reduction to ferro-chromium, which is employed in making chrome steel. By far the most part of the mineral produced is employed for the first purpose, for which only that of high grade can be economically used, while for the manufacture of ferro-chromium, which is growing in importance, and for furnace hearths (for which purpose chromite has been almost entirely supplanted by magnesite) ore of lower-grade suffices."

"Potassium bichromate is used extensively in the preparation of chrome yellow and chrome orange, which are employed as pigments in calico-printing; chrome black, used in dyeing; for the oxidation of caoutchouc and Berlin blue; the discharge of indigo blue; the bleaching of palm oil and other fatty substances; the preparation of mixtures for the heads of lucifer matches; and the preparation of mercurious chromate and chromic oxide, which are used as green pigments in the ceramic art. Potassium chromate is further used in the manufacture of aniline colours and chlorine gas, in de-fusel-ing brandy, and for many other purposes in the chemical industry, where it is an exceedingly important reagent."

"The potassium and sodium bichromates form the base from which numerous chromium compounds are obtained. Chromic acid is obtained by decomposing potassium bichromate with sulphuric acid. It is used instead of nitric acid in galvanic batteries. Neutral lead chromate, or chrome yellow, is prepared by precipitation of a solution of potassium chromate with a solution of lead acetate, or by the use of lead sulphate or chloride. This salt, which has a beautiful sulphur-yellow colour, is a valuable pigment. The basic lead chromate, known also as chrome-red, or Austrian cinnabar, is obtained from the yellow, or neutral chromate of lead, by boiling with a solution of potassium hydrate, or by fusion with potassium nitrate, the effect being that half of the chromic acid is withdrawn from the neutral chromate. The pigment known as chrome orange is a mixture in various proportions of the basic and neutral chromates of lead. Chromic oxide, or chrome green, is especially valuable as a pigment, being indelible, therefore it is employed in printing bank notes. Chromic oxide is prepared in various ways, one method consisting in heating a mixture of potassium chromate with sal-ammoniac, and subsequently treating it with water, leaving the insoluble chromic oxide as a fine powder. Another method is to heat an intimate mixture of potassium bichromate and charcoal. The hydro-oxide of chromium, known also as Guignet's green, is obtained by melting together at a red heat potassium bichromate and crystalline boric acid, the melted mass being leached with hot water, and the residue finely ground. Other salts of chromium employed in the arts are chromic chloride, basic ferric-chromate, and chrome alum, which is obtained in rather large quantities as a by-product in the manufacture of certain aniline colours, and is employed to some extent as a mordant in dyeing, for rendering gum and glue insoluble, for making woollen fabrics waterproof, and for some other minor purposes."

"Chromite has been used instead of dolomite and magnesite in the preparation of basic furnace hearths. It was employed with much advantage for this purpose at the Terre Noire Iron Works, in France, when they were in operation, and it is still used at the Alexandrovsky Works, in Russia. It has been employed at other open-hearth steel works in Russia and Finland, and at the Trollhätta and Kolsva Works, in Norway; but, according to Odelstjerna, the results were not satisfactory, and its use was soon discontinued."

"In preparing basic furnaces with chromite linings, all parts of the walls with which the metal bath and slags come in contact are laid with pieces of chromite cemented with a mortar consisting of two parts (by volume) of finely ground chromite and one part of lime burned as free from carbonic acid as possible. The hearth is made of stamped chrome ore, mixed with the same kind of mortar. The ore should be as rich as possible in chromic acid, containing 40 or 45 per cent. It is remarkable that with such high percentages of chromic acid in the hearth only small amounts are to be found in the metal made on it, but that is the case."

"Ferro-chromium, which is an alloy of chromium and iron, is made by reducing the mixed oxides of iron and chromium with charcoal in brasqued crucibles, adding fluxes (borax and glass) to slag off earthy matter and to prevent oxidation. This is the method employed at Unieux (France), Sheffield (England), and Brooklyn (N.Y.). At

Brooklyn finely pulverised chromite is reduced with charcoal in ordinary graphite crucibles, about 45 per cent. of ferro-chrome, assaying 30 per cent. chromium and 3 per cent. carbon, resulting. Ferro-chrome has also been made in blast furnaces, this method being in use at Terre Noire and Boucau (France), where five or six tons per campaign are made, with, of course, a heavy consumption of fuel. The percentage of chromium in ferro-chrome may be as high as 84 ; the alloy invariably contains carbon, and usually silicon and manganese."

"In making chrome steel at the Brooklyn Chrome Steel Works from 0·25 to 2 per cent. of ferro-chrome (30 per cent. chromium) is melted with Swedish or bloomary wrought iron in 70 lb. charges in crucibles in common crucible furnaces, which melt six charges per 24 hours, with a consumption of two parts anthracite to one of steel."

The principal uses of chrome-steel are in the manufacture of (1) armour plates for war vessels, (2) armour-piercing projectiles, and (3) shoes and dies for stamper batteries.

In the 16th Annual Report of the Geological Survey of the United States, 1894–5, Professor F. L. Garrison, makes the following remarks :—

"Since 1892 the progress which chromium-steel has made in the arts has been important. It not only continues to be an important element in the manufacture of projectiles, but it is coming to be used extensively in the fabrication of armour-plate. Although, according to the investigations of Hadfield and others, it appears that chromium does not of itself actually increase the hardness of steel, it seems that when it is combined with carbon and nickel in an armour plate, the steel is susceptible, by merely tempering, to a superficial hardness equal to that given by the Harvey process."

"As long ago as 1881 chrome-steel armour plates were made in France, and tested at the Gàvre proving grounds. The plates were composed of square slabs fastened to a solid backing of iron. The experiments were not successful, the first projectile shattering the plate into several fragments. This result was attributed to the iron-backing not being sufficiently solid."

"In 1891 experimental nickel-chrome-steel armour plates were made and tested in France. They contained 0·4 per cent. carbon, 1 per cent. chromium, and 2 per cent. nickel. The nickel and chromium were added in the form of ferro-nickel and ferro-chromium, or as double ferro-chromium and nickel. It seems that it was not until very recently, when the competition created by the so-called Harvey process demanded better plates, that these triple alloy chromium plates have met with success."

"The use of chromium-steel in the manufacture of armour-piercing projectiles has given this alloy probably more notoriety than its use for any other purpose. The precise action of the chromium in rendering the steel very hard, and the projectiles of exceptional strength and efficiency, has not yet been studied; we therefore know only in a general manner how the chromium acts. It has been repeatedly shown that the chromium itself will not harden the steel, and that it appears to act only upon the carbon; it would be of interest to know how the two elements react, not only alone in the steel, but in the presence of more or less manganese and silver."

"The analyses of all armour-piercing chromium-steel projectiles show a relatively high content of carbon—usually not less than 1 per cent. The secret of success in making armour-piercing projectiles of this steel undoubtedly lies more in the success of the tempering or hardening operations than in the constitution of the steel after certain general limits of composition have been observed."

"It is impossible at this present time to conjecture for what new uses in the arts chromium-steel will be adapted in the future. Its successful adaptation to the manufacture of war material is of quite recent origin, and it is doubtful if a better and cheaper alloy could be substituted possessing its peculiar and valuable properties. Hadfield has shown that chromium-steel may develop 60 per cent. more tensile strength, and over 4 per cent. greater elongation than the better grades of ordinary structural steel. If Hadfield's observations are correct, chromium-steel has doubtless a great future, since it should be made as cheap as any of the other alloyed steels, if not cheaper, and it is probably in many respects quite as good for most engineering purposes. At present its use is restricted to the manufacture of projectiles, the shoes and dies used in stamp mills for crushing ores, certain parts of the so-called burglar-proof safes, and occasional articles of no particular importance."

*The progress of Chromite Mining in New South Wales.*—The first attempt to mine for chrome-iron ore in the Colony was made in 1882, when about 100 tons were extracted from the Bowling Alley Point deposits, near the Peel River. The price realised for this parcel, however (viz., £3 10s. per ton), was not sufficient to yield a margin of profit, as the cost of carriage was considerably greater then than it is at the present time.

In 1891 an examination was made of the Gordonbrook chromite deposits by Mr. Geological-Surveyor David in response to a request made to the Department of Mines by several persons interested in mining. No attempt to work these deposits was, however, made until 1895, when thirty tons were extracted and shipped. The price obtained was not disclosed, but it was probably unsatisfactory, as mining operations were discontinued.

In 1892 a series of chromite deposits in the Mooney Mooney Range, about four miles to the north-east of the Coolac Railway Station, was opened, and in the years 1894 and 1895 over 2,000 tons of ore were extracted and despatched from what is now known as the Vulcan Mine.

The success which followed the opening of these mines drew attention to another group of chromite deposits in the neighbourhood of Mount Lightning, about five miles southerly, and about eighteen miles from Gundagai. These are known as Quilter's Mines and the Mount Mary Mine.

In consequence of the active operations which may be said to have commenced in this District in 1893, prospecting for chromite soon became general in all the serpentine belts known to exist in the various parts of the Colony. Success, however, has not attended the industry in any district except those already alluded to, the reasons, probably, being the inferior quality of the ore obtained in some instances, and the prohibitive cost of land carriage in others.

The price obtainable at present is about £3 15s. per ton (f.o.b.) for 50 per cent. ore, and 2s. per unit in excess of that percentage. Ores of lower grade are not marketable at anything like proportionate values, but it is hoped that as the consumption of the metal increases, as there appears to be every probability of its doing, and as the higher grade deposits become exhausted, ores of a poorer quality, which are known to exist in large quantities in different parts of the Colony, will be worked at a profit.

*List of localities of known deposits of Chromite.*—The following register of chromite occurrences, with notes and descriptions, was prepared in 1898 by Mr. J. E. Carne, Geological Surveyor, who personally inspected many of the deposits. It has now been brought up to date.

*Adjungbilly Creek, Parish of Darbalara, County of Buccleugh.*—On the south side of Mount Lightning, close to the Adjungbilly Creek, Messrs. Carroll and Gillespie were working on tribute an area on Mr. Quilter's property, known as the Mount Mary Mine. At the time it was inspected in 1895, about 400 tons had been despatched, averaging, according to the tributor's statement, from 48 to 49 per cent. The main deposit was being worked by means of an open cut about fifty feet long, and twenty to thirty feet deep. The ore exposed under foot was solid, and about seven feet in thickness, whilst a wedge of ore in the upper workings was left standing about twelve feet high, and ten feet thick. Several smaller bunches were exposed by shallow cuts and trenches high up the slope of the mount. The most important of the new finds was situated near the top of the mount, where a solid bunch about ten feet by four feet outcropped above the soil.

On the south side of Adjungbilly Creek, on the continuation of the serpentine ridge, Welch's Mine is situated. The only known deposit in this mine was exhausted for a yield of about 220 tons.

*Angular Creek, County Murchison.*—Chrome has been reported from this locality, but no particulars are known.

*Attunga and Manilla.*—Between these localities a serpentine belt extends in a N.N.W. direction. Several chromite deposits have been reported in it by Mr. C. S. McGlew; but, so far as his prospecting extended, none were of sufficient size to induce mining for export.

*Armidale.*—Samples submitted for assay in 1884 and 1888 from the Armidale District yielded 42·5 and 54·19 per cent., respectively.

*Barraba.*—Chromite from this district assayed in 1888 and 1895 yielded 40 to 44 per cent.; another sample in 1898 yielded 42·98 per cent.

*Berthong Run, near Wallendbeen.*—Mr. Geological-Surveyor J. B. Jaquet has described the Berthong chromite deposits as follows:—"Chromite has recently been discovered upon Berthong Run, but nothing has yet been done in the way of proving the extent of the deposits. In the bed of Berthong Creek a shallow trench of five feet long and two feet broad has been cut through a mass of this mineral. Chrome ore has also been found in a shallow trench put down upon the banks of a tributary of Berthong Creek. In the vicinity of the discoveries, and over a large portion of the serpentine zone, the bedrock is hidden by a shallow alluvial deposit, and it will be necessary for prospectors to find the ore bodies below." Samples forwarded from the above described deposits yielded from 39·5 to 54·04 per cent.

*Bingara.*—Chromic iron deposits have been noted at Spring Creek, about three miles south-easterly from Bingara, by Mr. T. W. E. David, Geological Surveyor, who reported that the serpentine in which they occur "forms an eruptive dyke from three to five chains wide, striking either north-westerly or northerly. Segregated masses of chrome iron are observable at intervals in the serpentine," and one bunch is stated to measure about seven feet by six feet. A sample forwarded from Spring Creek for assay in 1898 yielded 47·26 per cent. Two other assays are recorded from the Bingara district, viz., 40·87 and 41·21 per cent., the localities being, respectively, twelve and fourteen miles south of Bingara.

*Bowling Alley Point, near Nundle, Peel River.*—As already mentioned, the deposits of this locality were the first opened in the Colony, 100 tons being mined in 1882. The late Mr. C. S. Wilkinson, F.G.S., Geological Surveyor in Charge, in one of his reports states that "on a high range about one mile north-east from Bowling Alley Point occurs a lode of almost pure chromite of variable thickness. In one place, at the junction of diorite and serpentine, it crops out on the surface, twelve feet wide." Professor Liversidge, in his "Minerals of New South Wales," states that "the outcrop is about 700 feet above Bowling Alley Point, and the apparent thickness of the vein is in one part some forty odd feet; one huge block of the mineral lying loose on the surface measures twelve feet long by six feet high and five feet wide." There is no doubt that this deposit, like all the others which have been prospected in different parts of the Colony, is not really a lode, but a bunch or segregation in the serpentine. A specimen from this locality is reported by the last-mentioned author to have contained 64·72 per cent. of chromium sesquioxide, and 21·11 per cent. of iron protoxide. Other assays in 1892 are recorded varying from 37·42 to 47·04 per cent.

*Brawlin, seven miles south-east of (from foot of Cowong Range).*—A sample forwarded for assay, said to be from the above locality, yielded 31·13 per cent.

*Brungle Creek, Parish of Wyangle, County of Buccleugh.*—The Emu and Mount Miller Mines occur on either side of this creek, near the crossing of the Tumut-Tomorrowmah road. The serpentine is here deeply intersected by the creek and its tributaries. The Emu Mine at the time of inspection consisted of two bunches of chromite, one rather superficial, the other of better promise as regards size, but not as regards quality. Abundant water supply in close proximity to both the mines mentioned should afford the best means of ensuring a high grade product for export.

Mount Miller Mine is situated high upon the range on the opposite side of the creek. The deposits here are very small at the surface. A sample from the outcrop yielded 48·13 per cent. Other assays from this locality have yielded from 32·16 to 52·54 per cent.

*Clarence District.*—See Gordonbrook.

*Coolac.*—See Wright's and Vulcan Mine, Mooney Mooney.

*Cootamundra.*—Assays are recorded of samples purporting to come from this locality, but which may possibly mean either Berthong or Coolac; they yielded from 45·75 to 57·82 per cent.

*Copmanhurst.*—Probably identical with Gordonbrook. Assays recorded from 40·71 to 45·45 per cent.

*Crow Mountain.*—An assay of a sample from this locality in 1898 yielded 27·32 per cent.

*Darbalara Parish, County of Buccleugh.*—See Quilter's Mines.

*Deepwater district.*—A sample described as coming from the Deepwater District was assayed in 1898, and yielded 41·74 per cent.

*Emu Mine.*—See Brungle Creek.

*Eurongilly.*—On Mr. Keogh's private land a small bunch of low-grade chromite was noted, which had been broken from a loose block found in the soil, which is deep here. The country consists of talcose slate. Assays are recorded from 40·9 to 41·38 per cent.

*Gordonbrook, Clarence River.*—Mr. Geological-Surveyor David reported on the occurrence of chromite deposits in this locality in 1891. They occur in the Parish of Pucka, about thirty miles north west from Grafton, at Oakey and Fine Flour Creeks. Mr. David says, "The deposits of chromite in this neighbourhood form two principal groups. . . . They both occur in serpentine at a short distance from the edge of the Clarence Series. . . . Besides these two formations a third is developed, which may be described as a fine-grained, greenish-black rock, slightly crystalline, and probably a highly altered rock, which might be termed epidiorite. . . . This rock appears to have been intruded by the serpentine and the deposits of chromite, marked A on the plans herewith, occur chiefly along the junction line of this rock with the serpentine." In connection with the first group (A) in Portion 7, Parish of Pucka, Mr. David measured the two larger bunches as twelve feet by twelve feet, and twenty-four feet by eighteen feet. In the latter the chromite was a good deal mixed with serpentine, and would require dressing to render it marketable. Deposit B is described as forming a bluff on the left bank of Oakey Creek, about two miles north-westerly from the first group. The second group consists of two bunches—the main one about ninety feet, by thirty-six feet at its maximum width. The quality is reported as superior to that of A group. At the time of inspection these chromite deposits were not proved beyond a few feet, except in the main deposit of the second group (B), of which a natural section is available down to twenty feet in the creek channel. Mr. David estimated that the known Gordonbrook deposits would yield, approximately, 20,000 tons of chrome ore if it extend to a depth equal to its length, viz., 90 feet. Samples selected at the time of inspection yielded from 40·25 to 55·27 per cent. Other analyses by Mr. W. A. Dixon, F.C.S., were quoted in Mr. David's report as yielding from 39·7 to 48·61 per cent. Earlier assays (in 1886) are recorded as giving from 28·44 to 47·70 per cent. of sesquioxide of chromium.

Two attempts to work these deposits were made, viz., in 1891 and 1895, but neither was successful. Probably the cost of carriage was one of the chief causes of failure. The ore has to be conveyed by teams over a rather rough road for a distance of about twenty-four miles from the mines to Copmanhurst, the nearest navigable point on the Clarence River.

*Gundagai District.*—See Mooney Mooney, Vulcan, Quilter's, Adjungbilly, and Kangaroo Mine.

*Gwydir River.*—Chromite is reported from the Gwydir River and its tributaries (See Bingara).

*Gulgong* (?).—A sample of rich chromite received in 1877 is described as having come from Gulgong, but no analysis or particulars are recorded.

*Grenfell.*—From near Grenfell a sample yielding 43·22 per cent. is recorded.

*Harden, County of.*—See Mooney Mooney.

*Houlahan, Parish of, County of Clarendon.*—Chromite from this locality yielded 40 71 per cent.

*Ironbark and Barraba.*—Chromite from the serpentine of this district has been assayed for a yield of 46·45 per cent.

*Ironbarks.*—Chromite has been reported from between Ironbarks and Mudgee, but there are no particulars on record.

*Jindalee.*—A sample received in 1899, and said to come from Jindalee, yielded 36·16 per cent. of chromium sesquioxide.

*Kangaroo Mountain, Kangaroo Mine, Parish Wagara, County of Buccleugh,*—The Kangaroo mine is situated in Portion 128. It was opened in 1894 by Mr. M. Constable, under agreement with Mr. Robert Owen, the owner of the land. A report on this deposit was furnished by Mr. Geological-Surveyor J. E. Carne, who describes it as one of the most important on the field, both as regards extent and quality. At the time of inspection, in February, 1895, the output was averaging about 100 tons per week, and about 1,200 tons in all had been despatched up to that date. Down to thirty feet the main open workings averaged about seventy-five feet by twenty-five feet by thirty feet. At this point the dangerous open-work system of mining was abandoned in favour of a safer method of shafts and levels.

For about 200 feet the ore body was exposed by open cuts. At the surface the solid chromite was narrow, but opened to about eighteen feet in the widest part. In the open workings, at the 30-foot level, the chromite exposed measured about fifty-four feet by a width of four feet.

The quality of the ore proved consistently good, the lowest average in the account sales of 1,230 tons despatched to the date mentioned was 53 per cent., and the highest was 57 per cent. of chromium sesquioxide.

In addition to the Kangaroo Mine, about twelve other smaller deposits were discovered which yielded about seventy-five tons of marketable ore. Other pockets were known at the same time, but had not been opened.

*Keefe's Mine, between Brungle and Bumbolee Creek, County of Buccleugh.*—At the time of Mr. Carne's inspection (February, 1895), little work had been done at this site, which is on private property. A small chromite bunch or pocket, about six feet long by two feet six inches wide, had been opened for a few feet only. Most of the ore was mixed with country, and required dressing. Other deposits were reported on this property, and latterly more attention has been given them. Distance of team carriage, however, is reported to have prevented profitable mining being maintained at the present time.

*King, County of, near Yass.*—Chromite has been noted in this county, but no particulars are available.

*Manning River, Upper.*—A sample, said to come from the Upper Manning River, was assayed in the Department of Mines for a yield of 46·19 per cent. In 1899 another sample, from Little Dingo, Manning River, yielded 49·34 per cent.

*McInerny's Mine, near Bumbolee Creek, eight miles from Tumut, and situated near the south-west corner of portion 351, Parish of Mundongo, County of Buccleugh.*—This site was also inspected by Mr. Carne, in February, 1895. A few small bunches were then being prospected, but the quality of the ore was inferior. This mine was the furthest southerly in the serpentine belt at the date mentioned, the distance from the Gundagai Railway Station being about thirty miles.

*Molong, fitfeen miles west of.*—A sample of chromite bearing this inscription was assayed for a yield of 24·08 per cent.

*Moonbi, twelve and fifteen miles from.*—Numerous samples have been forwarded from this district. Assays are recorded from 39·21 to 43·30 per cent.

*Mooney Mooney.*—See Wright's and Vulcan Mine.

*Mount Lightning.*—See Quilter's and Mount Mary Mines, and Adjungbilly.

*Mount Mary Mine.*—See Adjungbilly.

*Mount Miller Mine.*—See Brungle Creek.

*Murrumburrah.*—Chromite, reported as coming from this district, yielded 44·40 per cent.

*Nundle.*—See Bowling Alley Point.

*Oakey Creek.*—See Gordonbrook.

*Paling Yard and Dry Diggings, between.*—Chromite sent far away from this locality yielded 40·67 per cent.

*Port Macquarie.*—From the serpentine of Port Macquarie samples of coherent chrome-iron sand have been received, which yielded 48·24 per cent. of chromium sesquioxide, and 1·29 per cent. of cobalt protoxide. No solid chromite pockets have yet been discovered in the neighbourhood, and the mode of occurrence of the compact sand points to the natural concentration of small particles of chromite, liberated by weathering and decomposition of the serpentine in which they were previously disseminated. Magnetic iron oxide occurs at Port Macquarie under similar conditions.

*Pucka.*—See Gordonbrook.

*Quilter's Mines.*—Of the six deposits of chromite described by Mr. Carne, in his first report (1892), as occurring on Mr. John Quilter's property at Mount Lightning, three had been opened at the date of his second inspection in February, 1895, and 1,100 tons of ore had been despatched mainly from two of the deposits. Both the latter presented very small outcrops. The open-cut system had been adopted in winning the ore, but at twenty feet it had to be abandoned in favour of safer methods. Two of the larger deposits are, unfortunately, of very moderate grade, and hence have, so far, been little worked. No doubt advantage will yet be taken of them when more systematic grading and dressing is adopted. Four consignments, aggregating 800 tons, from the deposits opened at the date above quoted, yielded from 49·8 to 56·5 per cent. of sesquioxide of chromium. By careful blending a considerable quantity of the abundant lower grade ore could be worked in with the first grade, and a uniform percentage of, say, 50 be maintained.

The ore in this mine was conveyed by gravity from the mountain on a wire rope to the opposite side of the Murrumbidgee River, the bags of ore being suspended by hooks with running blocks.

*Shoalhaven.*—A sample of chromite, assaying 49·55 per cent., was said to come from the above locality, but its correctness is doubtful.

*Stony Batta, County Hardinge.*—Chromite reported from here, but no particulars available.

*Tamworth District.*—From twenty miles north, twenty-six miles north-west at Hall's Creek, and from Manilla Range, samples of chromite have been received, yielding from 40·41 to 46·59 per cent.

*Tumut District.*—See Darbalara, Wagara, Brungle, and Wiangle Parishes, County of Buccleugh.

*Uralla.*—Chrome iron ore, said to come from Uralla, was assayed in 1898, for a yield of 52·41 per cent. of chromium sesquioxide.

*Vulcan Mine, Mooney Mooney Range, four miles north-easterly of Coolac Railway Station.*—As already stated, the group of deposits in the neighbourhood of this mine were the first opened in the Gundagai district, under the name of Wright's Mine. At the time of Mr. Carne's first inspection in 1892, a little surface prospecting or uncovering had been done. The largest deposit thus exposed was about sixty-three feet by twelve feet at the greatest width, with a depth of ten feet. The average width of chromite was about seven feet. About two chains further down the slope of the hill another deposit, partly exposed by shallow openings, measured forty-five feet by five feet. Selected samples from the two outcrops yielded 47·68 and 48 per cent. of $Cr_2O_3$.

Estimates of the probable quantity of ore available in these deposits, based on the supposition that they were lens-shaped, and that the vertical extension might be assumed to be equal to about half the horizontal (owing to weathering of the exposed surface) tallied very closely with the actual amount won during mining operations. At the time of Mr. Carne's second visit in February, 1895, about 1,200 tons had been raised and despatched; and, judging from the appearance of the dangerous open workings—which were just then being abandoned on account of risk—the total output would be in the neighbourhood of the former estimate, viz., 2,250 tons.

*Wagara Parish, County of Buccleugh.*—See Kangaroo mine.

*Walcha District.*—A sample of chromite, forwarded from this district, assayed 48·26 per cent.

*Wallendbeen.*—See Berthong.

*Warialda, twelve miles south of.*—In 1898 a sample of chromite from this locality assayed at the rate of 41·08 per cent. of $Cr_2O_3$.

*Welch's Mine.*—In Portion 173, on the west side of the continuation of the serpentine range, south of Adjungbilly Creek, Messrs. Welch and Springthorpe, extracted 220 tons from a deposit, which gave out abruptly, and was abandoned,

*Wright's Mine.*—See Vulcan.

*Wyalong, near.*—A sample submitted for assay was said to be from this district, but the information is doubtful. It assayed 37·35 per cent.

*Wyangle, Parish of.*—See Brungle Creek.

*Young District.*—Chromite occurs about twenty miles from Young. A little attention has been given to it, and a number of assays made, ranging from 42·46 to 48·35 per cent.

*Yulgilbar, Clarence River.*—Chromite has been received which was reported to have come from the ranges between Solferino and the local cinnabar mine; and, as serpentine occurs in this locality, the report is probably correct.

Production of Chromite.

| Year. | Quantity. | Value. |
|---|---|---|
| | Tons. | £ |
| 1882 ... ... ... ... | 100·00 | 325 |
| 1894 ... ... ... ... | 3,034·30 | 12,336 |
| 1895 ... ... ... ... | 4,229·45 | 13,048 |
| 1896 ... ... ... ... | 3,851·75 | 11,280 |
| 1897 ... ... ... ... | 3,379·55 | 10,269 |
| 1898 ... ... ... ... | 2,110·90 | 6,301 |
| 1899 ... ... ... ... | 5,242·70 | 17,416 |
| Totals ... ... | 21,948·65 | 70,975 |

# TUNGSTEN.

Ores of tungsten, though occurring in a number of localities in New South Wales, have not hitherto being found in any very extensive deposits. They occur, for the most part, in granitic rocks, and are frequently associated with tinstone (cassiterite), bismuth ores, and molybdenite. In some of the stanniferous leads the stream tin is mixed with a variable proportion of wolfram, and the two minerals are also found associated in quartz veins, and as impregnations in metalliferous greisens. Occasionally veins of nearly solid wolfram are found intersecting granitic rocks.

The principal ores of tungsten found in the Colony are wolfram and scheelite, while stolzite, or tungstate of lead, though not sufficiently plentiful to be of commercial importance, occurs in beautiful crystals in the Broken Hill Silver Lode.

*Scheelite*, or tungstate of lime ($Ca\ WO_4$) contains 80·6 per cent. of tungstic acid. Specific gravity, 5·9—6·1 ; lustre vitreous, inclining to adamantine, colour white, pale yellow, brownish, greenish, or reddish ; is the richest ore of tungsten.

*Wolfram* or *Wolframite*, tungstate of iron and manganese ($(Fe\ Mn)\ WO_4$), contains 76·6 per cent. of tungstic acid. Specific gravity, 7·2—7·5 ; lustre, metallic to resinous ; colour, brownish red to brownish black. Is the most common ore of tungsten.

*Stolzite*, or tungstate of lead, $Pb\ WO_4$, contains 51 per cent. of tungstic acid ; lustre, resinous ; colour, green, yellowish gray, brown, and red. Is a comparatively rare mineral, but has been found near Peelwood, and in several beautifully crystallised varieties in the Broken Hill Silver Mines.

*Uses of tungsten.*—The following statements are taken from "The Mineral Industry," for 1893 and following years :—"The chief use of tungsten is in the preparation of ferro-tungsten for making tungsten steel, concerning which the reader is referred to the various treatises and technical publications on steel. Tungstate of soda has been employed as a mordant in dyeing cloth, and for the impregnation of vegetable tissues, linen and cotton, to render them non-inflammable, which is a remarkable property possessed by the substance. Its consumption for this purpose has never become large, however, as cheaper salts, like alum, can be used for the same purpose. Ferro-tungsten, the alloy of tungsten and iron, is easily prepared from wolframite or scheelite. The mineral is pulverised and roasted to drive off any sulphur or arsenic with which it may be contaminated. It is then reduced, preferably with iron or ferric-oxide, in brasqued crucibles, a long and strong heat being required. As obtained, the alloy often appears as a dark, heavy, slightly sintered mass, containing varying amounts of tungsten, which unites with iron apparently in all proportions—at least up to 80 per cent. As tungsten raises the melting point of iron, however, alloys with more than 40 per cent. of it are seldom made. Ferro-tungsten may also be made by reduction in the blast furnace, but the demand for it at present is too small to make its production on so large a scale necessary."

"At the Krupp Works (Germany) about 75 tons of tungsten are used yearly in the manufacture of guns, and even in steel rails a small quantity is used, the effect being to produce a very dense, tough, and strong steel, with excellent wearing and resisting qualities. The German Government has experimented considerably with pure tungsten added to lead in the manufacture of bullets, as it produces a bullet with much higher penetrating power than ordinary lead, and yet does not interfere with the fusibility of the metal. Nearly all the crucible steel makers in Sheffield use tungsten to a greater or less extent; while Osborne and Company, the manufacturers of the 'Mushet' steel in Sheffield, have, perhaps, used tungsten longer than any other steel concern."

"The importance of tungsten in industry is due to its hardness, which is greater than that of any other commercial metal; to its high specific gravity, which is over 19, or about equal to that of gold; and to its property of making steel self-hardening. The last-named property is by far the most important, and the chief commercial use of tungsten is in the manufacture of steel, for which purpose the greater part of the metal produced yearly is used. Its employment for this purpose is more general in Europe than in this country (America). In Germany, especially in the Krupp Works, nearly all the tool steel manufactured is alloyed with tungsten, and in England several of the special brands for which the Sheffield makers are famous owe their good quality to the use of this metal. The advantages of tungsten steel are its hardness* and in its property of hardening in the air after forging or heating. This avoids the necessity of retempering a tool every time it has to be resharpened in use, and also where steel is used for cutlery and similar purposes it prevents the gradual loss of temper which is familiar to all who have to use knives and similar cutting instruments.

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* Metcalf states (in Trans. Am. Soc. C.E., Vol. XXVII., pp. 394, 395: "It is popularly believed that tungsten renders iron very hard. . . Nevertheless this belief is erroneous, for if a steel be chosen not excessively high in manganese and carbon, as all the self-hardening specimens are, then no amount of tungsten will make it file-hard if allowed to cool spontaneously in the air. The true function of this element is to delay the rate of change of carbon when either going into or out of solution. . . . Tungstic steel is neither so hard nor so strong as plain carbon steel; hence there is no advantage in using it except for special purposes." Howe, in his "Metallurgy of Steel," states that the hardness of tungsten steel is not impaired by heat, and as a consequence may be driven much faster than carbon steel when used for machine-cutting tools.

On the other hand, tungsten steel is costly, and its forging and working require exceptional skill; the better the steel the more carefully it has to be treated."

"The use of tungsten in manufacturing armor-plates and projectiles has been suggested. There is little doubt that steel alloyed with a suitable proportion, probably 5 or 6 per cent., of tungsten, would be quite as hard as nickel-steel plates prepared by the Harvey process, but the great expense has prevented the use of any such plates in practice thus far."

"French experiments have also shown that a small percentage of tungsten greatly increases the carrying power of spring steel. Chamond claims that tungsten steel is about one-third stronger than the best carbon spring steel."

"Other uses have been suggested by its hardness; among them the use of a small percentage in place of copper to harden metallic aluminium, its resistance to oxidation making it much superior to copper for that purpose. A small percentage of tungsten also greatly increases the hardness and resistance to abrasion of gold and silver coins. The metal has been used experimentally in the German army and in the United States army for bullets. For this purpose an alloy of about 35 per cent. of tungsten and 65 per cent. of steel is used to form a thin shell which carries a lead core. A solid bullet of this alloy would be too costly, but the experiments made seem to show that the compound bullet fills satisfactorily the requirements of the modern rifle with its improved power and high initial velocity. These requirements, as is well known, are not met by the old-fashioned lead bullet."

"Tungsten has been used, on account of the property which it possesses of increasing the elastic limit of steel, in making the sounding-plates of pianos. Another remarkable property which it has is that of increasing very much the magnetism of steel. Alloys of other metals besides iron are used in the arts, among them several bronzes of various composition, usually of copper and zinc with varying percentages of tungsten. These are found to give excellent results."

"In 1897 there were no developments worthy of special note except in the preparation of the fluoroscopes used in X-ray observations, in which a tungsten compound is used, and in the separation of wolframite and cassiterite, which was accomplished very successfully by the Wetherill magnetic machines."

Wolfram and tinstone are found associated with one another in a good many localities, notably at Pulletop, near Wagga Wagga, and at Jingellic on the Murray River, above Albury. At the former place the two minerals occur in about equal proportions, and their respective specific gravities are so nearly alike that they cannot be separated by ordinary mechanical appliances. For this reason it has hitherto been found impossible to work the deposits at a profit; but in view of the successful separation, which is said to have been effected by the

Wetherill process, it seems probable that these deposits will be profitably worked in the future. The process consists in passing the pulverised and dried ore under the poles of powerful electro-magnets, when the wolfram is found to be sufficiently magnetic to be all extracted, and the tinstone is left. The method previously adopted in Europe for the treatment of such ores was to fuse them with carbonate or sulphate of soda; soluble tungstate of soda was thus formed while the tin was reduced to the metallic state.

According to Dr. G. Mackenzie, Manager of the Sydney Tin-smelting Works, the presence of more than 1 per cent. of wolfram in tin ore is objectionable in smelting operations.

The price of wolfram fluctuates very considerably, and has been as high as £80 and as low as £15 per ton for 70 per cent. ore within a comparatively recent period. Ore of as low a grade as 45 per cent. (of tungstic acid) has at times been marketable, but as a rule the recognised standard grade is 70 per cent. ore, which must necessarily be entirely separated from gangue.

The following is an alphabetical list of the localities where tungsten ores have been found, together with the available information in regard to their occurrence.

*Adelong.*—In his "Minerals of New South Wales," Professor Liversidge states :—"A specimen from the Victoria Reef Gold-mine, Adelong, was massive, but with a portion of a crystal showing on one side, of an amber colour, translucent, resinous lustre, brittle splintery fracture. Hardness 4·5; specific gravity, 6·097, associated with a dark green chloritic veinstuff. The following analysis was made by Dr. Helms :—

| | |
|---|---|
| Loss at red heat | ·25 |
| Tungstic acid | 79·53 |
| Lime | 19·14 |
| Alumina | ·58 |
| Magnesia | ·07 |
| | 99·57 |

*Armidale District.*—In the year 1886 a specimen of scheelite from near Gara Falls, about twelve miles from Armidale, was analysed in the Department of Mines, and yielded 47·9 per cent. of tungstic acid. In 1894 another sample of crushed scheelite from the Armidale District was found to contain 66·29 per cent. of tungstic acid, and in 1899 another sample from the same place yielded 67·75 per cent.

*Berridale.*—In 1891 Warden M. S. Love reported that permits under the Mining Act of 1889 had been granted to several persons to search for wolfram on W. Avery's conditional lease at Berridale, in the Parish of Coolamatong, twenty miles S.W. of Cooma, and he stated that a broken outcrop of quartz, containing wolfram, had been traced for 100 yards, running east and west. An assay, made in the Department of Mines, of a small sample from this outcrop, yielded 69 per cent. of tungstic acid.

In 1893, another sample of wolfram in quartz, from the same locality, was analysed in the Mines Department for a yield of 54·35 per cent. of tungstic acid, and Warden Love reported that prospecting operations were still going on in the district, and that the indications were considered very satisfactory.

*Bingara.*—In 1893 a sample of almost pure wolfram, from the Bingara District was analysed in the Department of Mines, and was found to contain 72·46 per cent. of tungstic acid.

*Bolivia.*—In 1898 a specimen of granite with wolfram was received in the Department of Mines from a locality three miles from Bolivia. The sample contained 26·20 per cent. of tungstic acid. Another specimen of wolfram and glassy quartz with felspar was received from near Bolivia in 1899, and was found to contain at the rate of 28·57 per cent.

*Bundarra.*—In 1891 a sample of quartz with wolfram associated with arseniate and arsenide of iron was forwarded from Bundarra, between Uralla and Inverell, and was found to contain 44·94 per cent. of tungstic acid.

*Burrowa.*—A specimen of scheelite received from Burrowa in the year 1891 yielded 31·65 per cent. of tungstic acid in the Laboratory of the Department. In the following year two specimens of wolfram, with quartz, from Frogmore, in the same district, were found to contain 51·67 and 62·67 per cent. respectively.

*Casino.*—In 1895 a specimen of scheelite from the Casino District was tested in the Laboratory attached to the Department of Mines, and yielded 75·20 per cent. of tungstic acid.

*Clive County.*—In 1892, a specimen of wolfram in siliceous gangue, stained green by arseniate of iron, was forwarded to the Department of Mines from the Parish of Binghi, County of Clive. On being tested it was found to contain 42·55 per cent. of tungstic acid.

*Cobar.*—A sample of wolfram in quartz was received in the Department of Mines, in 1895, from Cobar, and yielded 53·70 per cent. of tungstic acid.

*Cowra.*—In 1893, a specimen of wolfram from the Cowra District was analysed, and found to contain 67·80 per cent. of tungstic acid.

*Cooma.*—Wolfram, stated to have been found three miles from Cooma, was analysed in 1891, and yielded 54·95 per cent. of tungstic acid.

*Cordillera Hill, Tuena District.*—Stolzite and scheelite have both been found in the Cordillera Silver Mine. In 1886, a specimen of the latter mineral was analysed for the Department of Mines, and yielded 69·31 per cent. of tungstic acid.

*Deepwater.*—Quite a number of samples of wolfram have been received from time to time in the Department of Mines, from the neighbourhood of Deepwater. Particulars of the assays of these are given in the following table :—

| Date. | Description of Specimen. | Percentage of Tungstic Acid. | Locality. |
|---|---|---|---|
| 1892 | Wolfram in quartz ... ... ... | 47·02 | Near Deepwater. |
| 1892 | ,, ,, ... ... ... | 51·23 | ,, (Nine-mile). |
| 1893 | ,, felspar and quartz veinstone, stained with arseniate of iron. | 45·50 | Bald Rock, 20 miles from Deepwater. |
| 1893 | Wolfram ... ... ... ... | 73·10 | Deepwater. |
| 1894 | ,, ... ... ... ... | 68·50 | Near Deepwater. |
| 1894 | Picked wolfram ... ... ... | 68·75 | ,, |
| 1894 | Quartz, with wolfram and ilmenite | 49·50 | 10 miles east of Deepwater. |
| 1898 | Crushed sample ... ... ... | 64·50 | Deepwater. |
| 1899 | Wolfram ... ... ... ... | 61·65 | ,, |
| 1899 | ,, ... ... ... ... | 68·60 | ,, |
| 1899 | ,, ... ... ... ... | 71·25 | ,, |
| 1899 | ,, ... ... ... ... | 71·45 | ,, |
| 1899 | ,, ... ... ... ... | 48·75 | ,, |
| 1899 | ,, ... ... ... .. | 37·85 | ,, |

*Ding Dong.*—The late Mr. C. S. Wilkinson, Geological Surveyor-in-Charge, reported as follows in 1883 :—"Tin-bearing lodes occur at Ding Dong, between Deepwater and the Great Dividing Range. . . At Ding Dong, near the junction of the slate formation and granite, the latter, which is coarse-grained granite, contains irregular-shaped masses of greisen rock, composed of quartz and mica, in varying proportions. These masses appear to have been formed by segregation, and the tin ore occurs disseminated through them, chiefly in bunches. . . . . Wolfram is sometimes associated with the tin."

*Emmaville.*—In his "Geology of the Vegetable Creek Tin-mining Field," published by the Department of Mines in 1887, Professor David thus describes the occurrence of ores of tungsten in the Emmaville District. "An important vein of wolfram occurs in the Mole Table-land, thirteen and a half miles north of Emmaville in a direct line, but twenty-one miles distant by road. The point, at which the reef was observed to be rich in wolfram, bears west 36° south from the south-west corner of Portion 407, Parish of Rockvale, County of Clive, a quarter of a mile distant, and lies just outside the boundary of this parish, in the north-east corner of the Parish of Flagstone, County of Gough. The vein is, in places, from 10 to 12 yards wide, though probably not metalliferous throughout its entire width. Owing to the reef being covered over with iron-stained sandy soil, it is impossible to ascertain, by mere inspection, the average width or length of its outcrop, though surface indications favour the supposition that the reef is a strong one. The strike is about N. 40° E. As far as I am aware, this reef has never been prospected, and it is situated partly on Crown lands."

"Wolfram also occurs at the Gulf main vein, Hall's Grampians, Lee's Gully, and the Planet Mine, near the head of the Nine-mile Creek, Parish of Wellington Vale, County of Gough. Scheelite has been found in small quantities at McDonald's veins on the Glen Creek. The mineral is honey-coloured and translucent."

Two samples of wolfram from the Emmaville District were analysed in the Department of Mines in 1892; they yielded 64·06, and 68·03 per cent. of tungstic acid respectively.

*Elsmore, near Inverell.*—A specimen of wolfram in quartz was received from Elsmore in 1895, and yielded 67·70 per cent. of tungstic acid. In this locality there is a considerable development of stanniferous greisen; the tinstone is disseminated through the greisen in grains and crystals, and the denudation of this rock has resulted in the formation of important surface deposits of tin ore, which were extensively worked shortly after the discovery of payable tin in 1872. Veins or lodes of quartz and wolfram also intersect the greisen, and in places bunches of pure wolfram, eighteen inches in width, may be seen in the lodes. Little or no work has, however, been done in the way of proving these deposits, as they occur on alienated land.

*Eremeran Range.*—Samples of wolfram have been received from the south end of the Eremeran Range, and also from two miles east of the Eremeran Station homestead. The ore occurs in a quartz gangue in granite country. Assays of this ore in the Departmental Laboratory about eight years ago yielded from 62·5 to 72 per cent. of tungstic acid. In 1898 two more samples were received from the same locality, and these yielded 39·87 and 63 per cent. respectively. In 1899 another sample yielded 22·6 per cent. of tungstic acid.

*Glen Innes District.*—At Kingsgate, about eighteen miles from Glen Innes, wolfram occurs in small quantity in pipe-veins, associated with native bismuth, sulphide and carbonate of bismuth, and molybdenite. The gangue is quartz, and the pipe-veins, which vary from a few feet up to thirty or forty feet in diameter, occur in granite within a distance of about 400 yards from its junction with slate. These cylindrical veins outcrop at the surface and dip to the east or north-east at angles varying from 10° to 45°.

At Hogue's Creek, twelve miles north of Glen Innes, and about one mile from the Tenterfield Road, wolfram also occurs in association with similar ores. The late Mr. C. S. Wilkinson, Geological Surveyor-in-Charge, described these deposits in the year 1883 as follows:—"They form irregular veins and masses of quartz traversing a fine-grained micaceous felsitic rock, which is surrounded by altered sedimentary rocks. In one place this rock, for a length of about 100 yards, and a width of

15 yards, is traversed by a network of quartz veins. A small hole has been sunk here, and the stone taken from it contains bismuth ores, tin ore (cassiterite), molybdenite, arsenical pyrites, and wolfram. In another place, about 100 yards from that last-named, a mass of hard crystalline quartz, in size at the surface about 40 feet by 20 feet, has been opened for a few feet in depth. It contains bismuth and tin ores, together with a large quantity of wolfram. . . . I do not consider that the vein stuff here can be profitably worked for tin on account of the occurrence in it of so much wolfram."

Subsequently, these deposits were worked for wolfram, and some clean mineral was obtained; but the bulk of the ore, so far as it has been proved by mining operations, is below the marketable standard.

In 1898 a specimen of ferruginous quartz and wolfram was forwarded to the Department of Mines from a locality described as twenty miles from Glen Innes, on the Grafton Road. This specimen, on being assayed, was found to contain 67·3 per cent. of tungstic acid.

In 1889 a specimen of wolfram described as coming from Glen Innes yielded 66·80 per cent.

*Gundagai.*—A sample of wolfram in granite was received in the Department of Mines from the Gundagai District in 1892, and yielded, by assay, 61·44 per cent. of tungstic acid.

*Guyra.*—A sample of scheelite, from the Guyra District, was assayed in the Department of Mines, and yielded 75·60 per cent. of tungstic acid.

*Hillgrove.*—Scheelite occurs at Hillgrove, associated with stibnite (sulphide of antimony), in auriferous quartz reefs, in intrusive granite, near its junction with Carboniferous claystones. Both gold and scheelite have been won by means of tunnels driven into the hillside. At a depth of 300 feet below the surface, a large body of low grade scheelite ore was discovered, and was as much as three feet wide in places. In 1898, one ton and a quarter of good scheelite, value at £30, was obtained in this mine. In 1899, seventy-four tons of this mineral, valued at £2,910, were won at Hillgrove; but recently, owing to a sudden fall in the price of tungsten, the industry has been neglected.

*Inverell.*—Two samples of wolfram, containing 73·4 and 77·6 per cent. of tungstic acid, are recorded from the neighbourhood of Inverell. Allusion has already been made to the occurrence of wolfram in lodes intersecting greisen at Elsmore, in the Inverell District, and it is probable that the samples just alluded to are from that locality.

*Jingellic.*—About fifty miles above Albury, on the north bank of the Murray River, the Jingellic tin-bearing lodes occur in granite country. At least eight lodes are known, and some of them have been traced on the surface for about a mile. They vary in strike from east to north-east, and they are from ten inches up to six feet in width. The gangue consists of quartz, and the tinstone is associated with wolfram, tourmaline, and arsenical pyrites. Very little work has been done on these lodes, and it is probable that the association of the wolfram with the tin, and the difficulty of separating these two minerals, was the reason for the abandonment of the mines. In view, however, of the success which is said to have been attained in the dressing of tin and wolfram ores by means of the Wetherill Magnetic Separators, it is more than probable that the Jingellic lodes will soon be profitably worked.

*Mila.*—Small quantities of wolfram are known to occur in a quartz reef near Mila, about fourteen miles south of Bombala.

*Millthorpe.*—In 1899, a sample of scheelite received from near Millthorpe, on the Western Railway Line, was found to contain 75 per cent. of tungstic acid.

*Mount Sutton.*—A sample received in the Department of Mines from Mount Sutton, in the New England district, yielded by assay 71·22 per cent. of tungstic acid.

*Nangeribone Run, near Nymagee.*—A sample of quartz from this locality was found, on examination, to contain wolfram.

*Newstead.*—Samples of wolfram have been received from Newstead. Its conditions of occurrence are similar to those at Elsmore, four or five miles distant, where lodes containing this mineral intersect tin-bearing greisen.

*Peelwood.*—The occurrence of scheelite at this locality has been recorded, but as specimens are known to have been found at Cordillera Hill in the same neighbourhood, it is possible that the same deposit may be referred to. In 1886 a specimen said to have been found "near Peelwood," was assayed in the Department of Mines, and yielded 69·3 per cent. of tungstic acid.

*Pheasant Creek.*—At Pheasant Creek, in the Parish of Moogem, County of Clive, wolfram occurs, associated with bismuth and molybdenite, in pipe-veins in granitic rocks close to their junction with altered claystones. One of these pipe-veins has been worked for wolfram by Messrs. Low, Miller, and West. At a depth of twenty feet from the surface masses of native bismuth were met with.

*Pulletop and Clifton Runs, Wagga Wagga District.*—In the Parishes of Westby and Burrandana, County of Mitchell, wolfram is found in considerable quantities, associated with tinstone. The two minerals occur in quartz lodes intersecting granitic rocks near their junction with slate, and also as detrital deposits (derived from these lodes) in the alluvials in the vicinity of Pulletop Creek. Several attempts have been made to work these deposits since they were first discovered (in 1872), but the difficulty of separating the wolfram from the tinstone has rendered the venture unprofitable, and the mines have been abandoned. Average samples of the alluvial ore were assayed in the Department and found to contain 27·72 per cent. of metallic tin and 28·82 per cent. of tungstic acid. It is probable that this ore can be profitably treated by the Wetherill Magnetic Separators previously alluded to, and if so the deposits will doubtless be worked in the near future. In 1894 three samples from this locality were assayed in the Department of Mines, and were found to contain 62·2, 46·17, and 45·9 per cent. of tungstic acid respectively.

*Purnamoota, Barrier Ranges.*—In 1898 a sample of wolfram from Purnamoota was assayed in the Department of Mines, and found to contain at the rate of 62·1 per cent. of tungstic acid.

*Severn River, near Emmaville.*—In 1886 a sample of wolfram, said to have been found at this locality, was assayed in the Department of Mines, and yielded 74·41 per cent. of tungstic acid.

*Tenterfield district.*—In 1893 a specimen of granular wolfram in a clayey matrix, said to have been found in the Tenterfield District, was assayed in the Department of Mines and found to contain 57·25 per cent. of tungstic acid. A second specimen from a locality described as being seven miles from Tenterfield, yielded 40·2 per cent.

*Waukeroo, Barrier Ranges.*—Wolfram is said to have been found in this neighbourhood, but no particulars are recorded.

*Yeoval.*—A specimen of cupro-scheelite was identified by the Curator, in 1896, from Yeoval near Wellington. This mineral had only been previously reported from one locality in the Colony, namely, Peelwood.

Production of Wolfram and Scheelite.

| Year. | Quantity. | Value. |
|---|---|---|
| | tons. | £ |
| 1891 .. ... ... ... | 7·00 | 70 |
| 1892 ... ... ... ... | ............. | ............. |
| 1893 ... ... ... ... | 1·38 | 14 |
| 1894 ... ... ... ... | ............. | ............. |
| 1895 ... ... ... ... | 5·00 | 88 |
| 1896 ... ... ... ... | ............. | ............. |
| 1897 ... .. ... ... | ............. | ............. |
| 1898 ... ... ... ... | 10·25 | 310 |
| 1899* ... ... ... ... | 159·00 | 3,710 |
| Totals ... ... | 182·63 | 4,192 |

| | | |
|---|---|---|
| * Hillgrove, 74 tons | scheelite.. | £2,910 |
| Emmaville, 70 ,, | (?) wolfram ore | 200 |
| Deepwater, 15 ,, | ,, | 600 |
| | | £3,710 |

# MOLYBDENUM.

Molybdenum is a white metal, which, however, is not found in a native state. Its specific gravity is 9·01; it has a silvery lustre, and is as malleable as iron; it can also be welded, filed, and polished, and it takes up carbon by cementation.

The ores of molybdenum are the sulphide and the oxide, known respectively as molybdenite and molybdic ochre; and of these, the former is by far the most important, and forms the principal source of the metal.

*Molybdenite:* composition molybdenum disulphide ($MoS_2$); contains 60 per cent. of molybdenum; crystallises in hexagonal forms, also foliated, massive, in scales, and finely granular; laminæ very flexible but not elastic, sectile; unctuous to the touch; hardness 1—1·5; specific gravity 4·7—4·8; lustre metallic; colour lead-gray; leaves a bluish-gray streak on paper.

*Molybdite or Molybdic Ochre:* composition molybdenum trioxide ($MoO_3$); contains 66·7 per cent. of molybdenum; occurs in capillary crystallisations, tufted and radiated; also subfibrous massive, and as an earthy powder or incrustation; hardness 1—2; specific gravity 4·49—4·5; lustre of crystals silky to adamantine, pearly, earthy; colour straw yellow, yellowish-white.

*Wulfenite* is another molybdenum mineral found in New South Wales, but not so plentifully as those just mentioned. Its composition is molybdate of lead ($PbMoO_4$); crystallises in the tetragonal system, generally in square tabular crystals, also granular massive; hardness 2·75—3; specific gravity 6·7—7·0; lustre resinous to adamantine; colour wax yellow to orange yellow and bright red, also olive green, brown, yellowish-gray to nearly colourless; streak white; subtransparent to subtranslucent; brittle.

*Uses of Molybdenum.*—The following information is taken from Rothwell's "Mineral Industry":—"Molybdenum is used chiefly in the preparation of special steels, for which purpose it is employed in the form of dark blue, powdered metal, with 95 to 99 per cent. Mo; as ferro-molybdenum, with 50 to 55 per cent. Mo; and as molybdenum-nickel, with 75 per cent. Mo, and 25 per cent. Ni. For tool steel from 2 to 4 per cent. Mo is added; for other qualities from 1 to 2 per cent., according to what is desired. The influence of molybdenum on steel is similar to that of tungsten, but it gives greater toughness, while molybdenum steel is more readily worked when hot, and stands hardening better than tungsten steel."

"The properties of molybdenum steel have been described more fully by Prof. W. von Lipin, who made a series of tests on the relative resistance of tungsten and molybdenum steels prepared under the same conditions. Both steels were made in Siemens' regenerative furnaces, from a charge consisting for the molybdenum steel of 20·6 kg. basic open-hearth steel, 2 kg. Swedish charcoal pig-iron, 2·3 kg. Swedish charcoal blooms, 0·1 kg. ferro silicon, and 1 kg. molybdenum in metallic form, but combined with a small quantity of carbon. For the tungsten steel the charge consisted of 16 kg. basic open-hearth steel, 3·7 kg. Swedish pig-iron, 2·9 kg. Swedish charcoal blooms, 0·1 kg. ferro silicon, and 1·8 kg. ferro-tungsten, having 48 per cent. tungsten. Both steels were cast into ingots, which were afterwards rolled into rods of a suitable size for the testing machine. By analysis the percentage of tungsten was found to be 3·8, and that of molybdenum 3·7. The experiments showed that annealing makes molybdenum steel softer than tungsten steel, while high heating makes it harder. Oil tempering and high heating after hardening increased the limit of elasticity in the molybdenum steel. Common tempering in oil had a greater influence on the tungsten steel than on the molybdenum; but, on the other hand, the molybdenum steel was stronger than the tungsten after heating and hardening in water. Tungsten steel was more apt to split than the other when worked, and broke sooner when bent cold. The molybdenum steel withstood forging and hardening better than the tungsten steel."

"The value of molybdenum ore depends upon its richness and purity, and in 1899 was quoted at 240 dollars per long ton (New York) for ore averaging about 50 per cent. of molybdenum. The price in 1899 of metallic molybdenum, of 95 per eent. Mo. content and higher, was 1·36 dollar per pound."

*Preparation of metallic molybdenum.*—"The first process employed commercially in the preparation of molybdenum consisted in the reduction by carbon of molybdate of lime, the latter being easily obtained pure. After the reduction the lime was separated from the metallic molybdenum by treatment with hydrochloric acid. The molybdenum thus prepared contained about three per cent. of carbon This process was introduced in 1892, by Sternberg and Deutsch at their chemical works at Grunau, near Berlin, where they were able to produce as much as 200 kg. of metal per day, and sell it at 1·90 dollar per kg., or 86·5 cents per lb. Since that time Moissan has prepared pure molybdenum by igniting ammonium molybdate, and reducing with carbon the molybdenum dioxide thereby obtained, the oxide and carbon being mixed in the proportion of 10 to 1, and the reaction effected in the electric furnace. Properly prepared the metal can be obtained free from carbon, while metal contaminated with carbon can be refined by heating with molybdic oxide, at a temperature far below its point of fusion."

*Occurrence of Molybdenum Ores in New South Wales.*—Molybdenite, which is the principal ore of molybdenum, occurs most plentifully in pipe-veins at Kingsgate, near Glen Innes, and in the Jingera Mineral Proprietary Mines at Whipstick, near Panbula; in both these localities it is associated with ores of bismuth. In the Kingsgate deposits, the crystals of molybdenite have a diameter of as much as three inches, but in the Jingera mine they are much smaller, seldom exceeding half an inch in diameter.

The following is a complete list of the localities where molybdenum minerals have been found :—

*Bolivia*, County of Clive.—Molybdenite (Liversidge).
*Broken Hill.*—Wulfenite, with silver and lead ores.
*Bullin Flat*, near Goulburn.—Molybdenite (Liversidge).
*Capertee*, County of Hunter.—Molybdenite (Liversidge).
*Cleveland Bay.*—Molybdenite (Liversidge).
*Ding Dong*, ten miles east of Deepwater.—Molybdenite in quartz, associated with wolfram, mispickel, and bismuth ores.
*Glen Creek*, County of Gough.—Molybdenite (Liversidge).
*Goodrich Mine*, County of Gordon,—Molybdenite (Liversidge).
*Hogue's Creek*, twelve miles north of Glen Innes.—Molybdenite in large quartz lode, associated with wolfram, cassiterite, and bismuth (Porter).
*Jingera Mineral Proprietary Mines.—Vide Whipstick.*
*Kempsey*, near, County of Dudley.—Molybdenite (Liversidge.)
*Kiandra*, County of Wallace.—Molybdenite with quartz (Liversidge).
*Kingsgate*, eighteen miles south-east of Glen Innes.—Molybdenite in quartz in pipe-veins, associated with wolfram, and bismuth ores.
*Molonglo*, County of Murray.—Wulfenite (Liversidge).
*Mount Murulla*, Kingdon's Ponds.—Wulfenite (Liversidge).
*Mount Wingen*, near, County of Brisbane.—Wulfenite (Liversidge).
*Munmurra*, County of Bligh.—Wulfenite (Liversidge).
*Oban*, County of Clarke.—Molybdenite (Liversidge).
*Pheasant Creek*, Parish of Moogem, County of Clive.—Molybdenite in quartz in pipe-veins, associated with wolfram, and bismuth minerals.
*Tarana*, County of Roxburgh.—Molybdenite (Liversidge).
*Whipstick*, Jingera Mineral Proprietary Mines, fourteen miles west of Pambula.—Molybdenite in pipe-veins, associated with bismuth ores.
*Wilson's Downfall*, thirty miles north of Tenterfield, and one and a half mile west of Wilson's Downfall Post Office.—Molybdenite in vein of milky quartz traversing granite.

*Production of Molybdenite.*— Up to the present time only the Kingsgate Mines have produced any molybdenite for exportation; the following are the quantities produced :—

| | |
|---|---|
| 1885 ... ... ... ... ... | 2 tons. |
| 1888 ... ... .. ... ... | 2 ,, |
| 1894 to 1898 . ... .... ... | 36 ,, |
| | 40 tons. |

The ore is understood to have contained 55 per cent. of molybdenum; the price obtained for the last parcel was unsatisfactory, and consequently no further attempt was made to save the mineral.

*Photographed by E. F. Pittman.*

COAL CLIFF.

The site of the first discovery of coal iu Australia, in August, 1797. (The cliff is formed of the Upper Coal Measures, overlaid by the Hawkesbury Series.)

# PART II.

# Non-metalliferous Substances.

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## COAL.

PERHAPS the most important of the varied mineral resources of New South Wales is coal, for not only is the quality of our fossil fuel superior to that found in the other Colonies, but, in extent also, the deposits here are very much greater than in any other portion of Australia.

The coal from the different New South Wales Coal-fields varies somewhat in character and composition, and while in some districts the fuel is most suitable for steam-raising, in others it has a special value for gas-making, or for household purposes. One special advantage about these deposits is that, for a distance of about 200 miles, they extend along the seaboard, so that they are excellently situated for export purposes.

The possession of such immense stores of first-class coal appears to be a guarantee that Sydney must, in the near future, become the centre of the manufacturing industries of Federated Australia, for when intercolonial tariffs are removed it will be more profitable to carry on manufactures in proximity to the coal supplies, than to convey the fuel to distant centres of population for manufacturing purposes.

The discovery of coal in New South Wales dates back to August, 1797, the locality where it was first found being Coalcliff, on the coast to the north of Wollongong, in the southern coal-field. About a month later seams of coal were discovered in the cliffs at Newcastle, which place has since become the centre of export for the northern coal-field.

The following extracts in reference to the early discovery of coal in Australia are taken from a work by D. Collins, entitled "An Account of the English Colony in New South Wales," 1798, page 617 :—

"Information was also received through the same channel (letters from New South Wales in 1797) that a ship called the 'Sydney Cove' had been fitted out for Port Jackson from Bengal ; but springing a leak at sea, she was run ashore on the southernmost part of the coast of New Holland. Seventeen of the crew attempted to get to Port Jackson in their longboat, but were driven on shore and lost their boat. They then attempted to reach it by land, in which hazardous attempt only three of them succeeded, the others either dying on the route or being killed by the natives. They were eighty days in performing this journey, and reported that in their way they had found great quantities of coal. This was afterwards confirmed by the surgeon of the 'Reliance,' who went down to the wreck and brought specimens of it back with him, having found immense strata of this useful article."

In a second edition of the same book, published in 1802, the following statements occur, page 45 :—

"August, 1797.—Mr. Clark, supercargo of the ship 'Sydney Cove,' having mentioned that, two days before he had been met by the people in the fishing-boat, he had fallen in with a great quantity of coal, with which he and his companions made a large fire, and had slept by it during the night. A whaleboat was sent off to the southward with Mr. Bass, the surgeon of the 'Reliance,' to discover where an article so valuable was to be met with. He proceeded about seven leagues to the southward of Point Solander, where he found in the face of a steep cliff, washed by the sea, a stratum of coal, in breadth about six feet, and extending eight or nine miles to the southwards. Upon the summit of the high land, and lying on the surface, he observed many patches of coal, from some of which it must have been that Mr. Clark was so conveniently supplied with fuel . . . . By the specimens of the coal which were brought in by Mr. Bass, the quality appeared to be good, but from its almost inaccessible situation, no great advantage could ever be expected from it, and indeed, were it even less difficult to be procured, unless some small harbour should be near it, it could not be of much utility to the settlement."

Notwithstanding the unfavourable opinions thus expressed, large shipments of excellent steam coal from these seams have, for many years past, been exported, the loading being carried on from jetties. In rough weather, however, there is very little protection for shipping on this coast; and in view of the importance of the southern coal trade, and the extent to which it would probably grow if better facilities for shipping were provided, the Government are now constructing a deepwater harbour at Port Kembla, which will enable the largest ocean-going vessels to take cargoes of coal with safety in the roughest weather.

The discovery of coal at the site of the present city of Newcastle is thus referred to by Mr. David Collins at page 47 of the work just quoted :—

"September, 1797.—This month began with a very vexatious circumstance. A boat named the 'Cumberland,' the largest and best in the Colony belonging to Government, was, on her passage to the Hawkesbury, whither she was carrying a few stores, taken possession of by a part of the boat's crew, being at the same time boarded by a small boat from the shore, the people in which seized her and put off to sea, first landing the coxswain and three others, who were unwilling to accompany them, in Pittwater in Broken Bay. Those men proceeded over-

*Photographed by E. F. Pittman.*

NOBBYS AND THE TOWN OF NEWCASTLE.

The cliffs in the background are where the second discovery of coal was made in September, 1797.

land to Port Jackson, where they gave the first information of this daring and piratical transaction. Two boats, well manned and armed, were immediately despatched after them, under the command of Lieutenant Shortland, of the 'Reliance.' One of these boats returned in a few days without having seen any of them, but Lieutenant Shortland proceeded with the other, a whale boat, as far as Port Stephens, where he thought it probable they might have taken shelter, but on the 19th, having been absent thirteen days, he returned without discovering the smallest trace of them or the boat. His pursuit, however, had not been without its advantage, for on his return he entered a river, which he named the Hunter River, about ten leagues to the southward of Port Stephens, into which he carried three fathoms water in the shoalest part of its entrance, finding deep water and good anchorage within. The entrance of this river was but narrow, and covered by a high rocky island lying right off it, so as to leave a good passage round the north end of the island, between that and the shore. A reef connects the south part of the island with the south shore of the entrance of the river. In this harbour was found a very considerable quantity of coal of a very good sort, and lying so near the water-side as to be conveniently shipped; which gave it, in this particular, a manifest advantage over that discovered to the southward. Some specimens of this coal were brought up in the boat."

The geology of the coal-bearing rocks of this Colony was first studied by the late Rev. W. B. Clarke, M.A., F.R.S., who determined their age and approximate extent. His work in this direction has been supplemented by Messrs. Stutchbury, W. Keene, C. S. Wilkinson, John Mackenzie, R. Etheridge, junior, Professor David, and others. The last-named gentleman has made a survey of the Newcastle and Maitland Coal-fields, and has shown by geological sections the relation of the coal measures of the Northern Fields to those of the Southern and Western Coal-fields.

As a result of the investigations of the abovementioned workers, the coal-bearing rocks of New South Wales may be classified as follows:—

| Geological Age. | Maximum Thickness of Strata. | Locality. | Character of Coal. |
|---|---|---|---|
| I. TERTIARY, *Eocene to Pliocene.* | about 100 ft. | Kiandra, Gulgong, Chouta Bay, &c. | Brown coal or lignite. |
| II. MESOZOIC, *Triassic.* | about 2,500 ft. | Clarence and Richmond Rivers. | Coal suitable for local use only. |
| III. PALÆOZOIC, *Permo-Carboniferous.* | about 13,000 ft. | Northern, Southern, and Western Coal-fields. | Good coal, suitable for gas-making, and for household and steam-raising purposes. |
| IV. PALÆOZOIC, *Carboniferous.* | about 10,000 ft. | Stroud ... ... | Very inferior coal, with bands, of no value. |

## I.—Tertiary Deposits.

Deposits of lignite or brown coal, of limited extent, have been found in deep alluvial *leads*, overlaid by basalt, in many of our gold-fields, as at Kiandra, Gulgong, Forest Reefs, near Millthorpe, &c. At the first-mentioned place the late Mr. C. S. Wilkinson found that the deposit of lignite had a maximum thickness of thirty feet. Another bed of the same material was described by the late Rev. W. B. Clarke as occurring on the coast at Chouta Bay, about forty-two miles to the north of Cape Howe. No attempt has ever been made to utilise any of these deposits as a source of fuel.

## II.—Triassic Deposits.

The Triassic Coal Measures are seen in the Clarence River Basin, which extends in a north and south direction for about 120 miles, while its greatest width from east to west is about 65 miles. The rocks forming this basin have been divided into the *Upper*, *Middle*, and *Lower Clarence Series*. At the base is a thick bed of coarse conglomerate, then from 300 to over 1,000 feet thick of shales, sandstones, etc. (*Lower Clarence*), with coal seams, then 100 feet of thick-bedded sandstones (*Middle Clarence*), which are probably the equivalents of the Hawkesbury Sandstone of the Sydney District, and above these again is a considerable thickness of shales (*Upper Clarence*), which may yet be found to contain coal seams.

At least five coal seams have been discovered in the Lower Clarence measures, varying in thickness from two to thirty-seven feet, but in every instance they are largely made up of bands, and it is a rare thing to find a layer of clean coal of more than one foot in thickness between the bands. The coal contains a large proportion of fixed carbon, and should, therefore, be classed as a steam coal; but, unfortunately, the percentage of ash is too high to allow of the fuel being exported for this purpose, and it is unsuitable for any other than local use. Possibly the proportion of ash might be brought down to reasonable limits by the use of coal-washing machinery, in which case the washed coal would be suitable for the manufacture of coke. The Clarence River coal is, as a rule, remarkably free from sulphur, and is comparatively smokeless.

The Clarence Basin extends northwards into Queensland, and at Ipswich thick and valuable seams of coal are worked on an extensive scale; it is not known, however, whether the Ipswich Measures are the equivalents of the Upper or Lower Clarence Series, though it is probable that they are the latter.

Again, on the western flanks of the dividing range, these Mesozoic rocks (the Middle Clarence Series) outcrop, and form the intake beds of the great Artesian Water Basin of New South Wales. In many of the artesian bores put down on the Western Plains, coal seams have been intersected, as proved by the pulverised coal brought up with the drillings; but, as the percussive drill (Canadian rig) is used for all these bores, no solid core can be obtained, and it has not been possible to ascertain the exact thickness, or the quality of the seams passed through. Although many thousand square miles of the north-western plains are thus, in all probability, underlaid by seams of coal, there is no likelihood of their ever being worked on account of their being associated with beds containing water under pressure (artesian water).

The Hawkesbury Series, which form the principal geological features of the country round Sydney, are believed to be the equivalents of the Clarence River beds, thus:—

| | | |
|---|---|---|
| *The Wianamatta Shales,* | equivalent to the | *Upper Clarence Shales.* |
| *The Hawkesbury Sandstones* | ,, ,, | *Middle Clarence Sandstones.* |
| *The Narrabeen Shales* | ,, ,, | *Lower Clarence Shales.* |

A seam of coal four feet thick, with bands, was described by the late Rev. W. B. Clarke as occurring in the Wianamatta shales at South Creek (between Sydney and Penrith), and thin seams (of about a quarter of an inch in thickness) of bituminous coal are not uncommon in the Hawkesbury Sandstones, but nothing like a workable deposit is known in any of the series. The most characteristic fossil plant remains in the Mesozoic coal-bearing rocks are *Tæniopteris Daintreei* and *Thinnfeldia odontopteroides.*

### III.—Permo-Carboniferous Deposits.

The Permo-Carboniferous rocks form the great storehouse of the productive coal seams of New South Wales. They cover an area estimated at from 24,000 to 28,000 square miles, stretching north, south, and west from the seaport of Sydney, and they constitute, on account of both the quality and the quantity of the coal contained in them, one of the most important assets of the Colony.

They have been classified as follows, in descending order, by Professor David:—

| Thickness. | |
|---|---|
| feet. | |
| 1,150 | 1. *Upper, or Newcastle Coal Measures,* containing an aggregate of about 100 feet of coal. |
| 2,000 | 2. *Dempsey Series;* freshwater beds, containing no productive coal. This series thins out completely in certain directions. |
| 570 | 3. *Middle, or Tomago, or East Maitland Coal Measures,* containing an aggregate of about 40 feet of coal. |
| 5,000 | 4. *Upper Marine Series;* specially characterised by the predominance of the fossil *Productus brachythærus.* |
| 130 | 5. *Lower, or Greta Coal Measures,* containing an aggregate of about 20 feet of coal. |
| 4,800 | 6. *Lower Marine Series;* specially characterised by the predominance of the fossil *Eurydesma cordata.* |
| 13,650 | |

The characteristic fossil plant genera of the Permo-Carboniferous coal measures are *Glossopteris*, *Vertebraria*, *Nœggerathia*, and *Gangamopteris*. Of these *Glossopteris* is equally common to the Upper, Middle, and Lower Coal Measures. *Vertebraria* and *Nœggerathia* are found chiefly in the Upper and Middle Coal Measures; while *Gangamopteris* is most abundant in the Lower or Greta Coal Measures, and occurs also at some depth down in the Lower Marine Series.

The Permo-Carboniferous measures are overlaid in many localities by the Hawkesbury Series (Triassic), and, as a rule (with at least one notable exception, like that of Pokolbin, near Branxton), there is an apparent conformability between them, so far as their stratigraphy is concerned; nevertheless the palæontological evidence shows a marked lapse of time between the deposition of the two formations, the Palæozoic marine fossils and plant remains of the Permo-Carboniferous rocks being succeeded by Mesozoic types of plants, freshwater shells (*Unio* and *Estheria*), fish, and labyrinthodonts, in the Hawkesbury Series.

1. *The Upper Coal Measures* are well developed in the neighbourhood of Newcastle, in the Northern Coal-field; also in the vicinity of Bulli, in the Illawarra District; and at and near Lithgow, on the western side of the Blue Mountains.

The following are the principal seams in the Upper Coal Measures near Newcastle, in descending order:—

| | | | | |
|---|---|---|---|---|
| 1. The Wallarah Seam | ... about | 11 ft. thick. | | |
| 2. The Four-feet Seam | ... ,, | 4 | ,, | |
| 3. The Catharine Bay Seam.. | ,, | 14 | ,, | |
| 4. The Great Northern Seam | ,, | 20 | ,, | |
| 5. The Burwood Seam | ... from | 6 to 8 ft. thick. | | |
| 6. The Dirty Seam ... | ... ,, | 6 to 10 | ,, | splits into two seams in places. |
| 7. The Yard Seam ... | ... about | 3 ft. thick. | | |
| 8. The Borehole Seam | ... from | 4 to 22 ft. thick, usually 8 to 9 ft. | | |

In the Illawarra Coal-field the following seams occur, in descending order:—

| | | | |
|---|---|---|---|
| 1. The Bulli Seam .... | ... from | 2 to 11 ft. thick, usually 6 to 7 ft. | |
| 2. The Four-feet Seam | ... about | 4 ft. thick. | |
| 3. The Thick Seam ... | ... ,, | 14 | ,, |
| (Several small seams.) | | | |
| 4. The Eight-feet Seam | ... from | 7 to 9 ft. thick. | |
| 5. The Bottom Seam . | ... about | 6 ft. thick, including numerous bands. | |

The Bulli seam is the only one which has been worked to any considerable extent in the Illawarra Coal-field, the coal in the lower seams

*Photographed by E. F. Pittman.*

THE UPPER COAL MEASURES, OVERLAID BY THE HAWKESBURY SERIES, CLIFTON, ILLAWARRA RAILWAY LINE.

having been found to be slightly inferior in quality wherever they have been tried, though it cannot be said that they have been prospected very thoroughly.

Valuable deposits of a variety of cannel coal, termed kerosene shale, occur in the Upper Coal Measures, as at Joadja Creek, Hartley Vale, Katoomba, Marangaroo, Capertee, etc. ; the kerosene shale at Doughboy Hollow, near Murrurundi, also probably belongs to this horizon.

As will be seen by the appended analyses, the coal from the three principal coal-fields, in which the seams of the Upper Coal Measures are worked, varies considerably in composition ; that from the Newcastle District is most suitable for gas-making and household purposes, and contains the least amount of ash, while the coal from both the Southern (Illawarra) and Western (Lithgow) fields is essentially a steam coal. The Southern coal contains less ash than the Western, but the latter is perhaps, more suitable for smelting purposes than the former.

As already stated, the Upper Coal Measures have been estimated to contain, in the aggregate, a thickness of about 100 feet of coal. Of this a thickness of from 50 to 60 feet has already been proved to be workable.

2. *The Middle or Tomago Coal Measures* outcrop in the neighbourhood of East Maitland, and dip under the Dempsey Freshwater Series and Upper Coal Measures. The following are the principal seams, in descending order :—

1. The Four-feet Seam, about 4 feet thick.
2. The Seven-feet Seam ,, 7 ,,
3. The Six-feet Seam ,, 6 ,,
4. The Three-feet Seam ,, 3 ,,
5. The Two-feet six inch Seam, about 2½ feet thick.
6. The Rathluba Seam, from 4 to 8 feet thick, usually about 5 feet.
7. The Morpeth Seam, ,, 4 to 6 ,, with bands. A rather dirty seam, scarcely workable.

It has been estimated that the aggregate thickness of the coal in the Middle Coal Measures is about forty feet. Of this total a thickness of about twenty feet of coal has been proved to be workable.

The Middle Coal Measures have not been found in either the Southern or Western Coal-fields, nor is it known how far towards the south or west they extend. It is probable that they have been overlapped by the Upper, or Newcastle, Coal Measures, and have thinned out against a rising surface of the underlying marine beds (Upper Marine Series).

3. *The Lower or Greta Coal Measures* outcrop over an irregular area between West Maitland and Greta, and extending to the north-east

and south-west of a line joining those two places. There are two seams worked in these measures, viz. :—

1. The Upper Seam, varying from 14 to 32 feet in thickness.
2. The Lower Seam, varying from 3 to 11 feet in thickness.

The average aggregate thickness of coal in these measures has been estimated at about twenty feet. In addition to this a few very small lenticular patches of Kerosene shale were found to occur in the upper coal seam at Greta, and a seam of cannel, about five feet thick, in the same upper coal seam at Homeville, near West Maitland. The Greta seams are, in some cases, inclined at a considerable angle, as at East Greta where the dip is 45°, and this fact renders mining operations rather more complicated than is the case with the seams of the Upper and Middle Coal Measures. The coal, however, is of excellent quality, and the percentage of ash is low, though the amount of sulphur is higher than in the other coals.

The Lower Coal Measures have also been recognised in the Clyde Valley in the extreme southern portion of the Illawarra Coal-field, but the seams here, as far as they have been prospected, do not appear to be workable under present conditions, the coal being slightly inferior and the seams thin. Kerosene shale, of somewhat inferior quality, has also been met with in this neighbourhood.

A long, narrow coal-field (known as the Ashford Coal-field) which appears to be of the age of the Greta Coal Measures, occurs to the north of the town of Inverell. It is about a quarter of a mile wide, and extends from a point about ten miles west of Inverell up to near Bonshaw on the Queensland border. It contains a seam of excellent coal, twenty-seven feet thick, which near Ashford dips to the west at a high angle (about 40°), and is in other places very much disturbed. The fossil plants *Glossopteris* and *Gangamopteris* are found in the sandstones and shales associated with it, the lastnamed plant being very abundant.

The following is the mean of four analyses of samples of the coal taken from a width of ten feet of the lower portion of the seam :—

| | | | |
|---|---|---|---|
| Hygroscopic moisture ... | ·71 | | |
| Volatile Hydrocarbons ... | 22·90 | Specific gravity ... | 1·348 |
| Fixed Carbon ... ... | 68·96 | Sulphur ... ... | ·412 |
| Ash ... ... ... ... | 7·43 | | |
| | 100·00 | | |

One pound weight of this coal will convert 13·83 lb. of water into steam.

The coal has a somewhat anthracitic character in places, and, as the analysis shows, is likely to prove an excellent fuel for steam or smelting purposes. Although no demand at present exists for coal in this remote part of the Colony, the future extension of the railways will doubtless result in the working of this seam. The following is a section of that part of the seam from which the samples of coal were taken :—

| | ft. | in. |
|---|---|---|
| Coal ... ... ... ... ... | 2 | 6 |
| Shale band ... ... ... ... | 0 | 2½ |
| Coal ... ... ... ... ... | 1 | 0 |
| Band ... ... ... ... ... | 0 | 1 |
| Coal ... ... ... ... ... | 6 | 2 |
| | 9 | 11½ |

Floor of seam ... Brownish clay shale.

A shaft about forty feet deep was put down on the seam near Fraser's Creek Station, and the samples and section referred to above, were taken from the bottom of the shaft. As the drive from the shaft bottom did not extend for more than ten feet from the floor of the seam, the remaining seventeen feet of coal could not be sampled.

*Volcanic rocks associated with the Permo-Carboniferous Coal Measures.*—In the Southern Coal-field there occurs, between the Upper Marine Beds and the Upper Coal Measures, a considerable thickness of volcanic rocks, consisting of sheets of basalt and augite-andesite, and beds of gray and red volcanic tuffs. These contemporaneous lavas and tuffs represent a maximum thickness of about 1,600 feet near Kiama, where the upper andesite sheet, which has a marked prismatic structure, is quarried for road metal. Further to the north, about four miles from Wollongong, a quarry is being opened in the same rock for the purpose of obtaining large blocks wherewith to construct the moles for the deep-water harbour at Port Kembla.

A similar thickness of doleritic andesites of a diabasic character were also described by Professor David in the Newcastle District, where they occur in two sheets, separated from one another by a bed of volcanic breccia.

In all the coal-fields of the Colony the Measures have been intersected by intrusive dykes, though their effect upon the coal is much more noticeable in some cases than in others. At Mittagong an intrusive mass of syenite has converted a seam of coal into typical anthracite ; this syenite is largely used for building purposes in Sydney and elsewhere, as it is an extremely durable as well as ornamental stone of a dark gray colour. In nearly all other instances the dykes which intersect the Coal Measures consist of dolerite or basalt, which is clearly post-Triassic in its age, as it has penetrated the Hawkesbury Series as as well as the underlying Permo-Carboniferous rocks. The dykes are of various widths, and have frequently been decomposed at the surface into a buff or grayish-white plastic clay. As a general rule, where a coal seam has been intersected by a dyke, the coal is found to be cindered or coked for a short distance (a foot or so) on each side of the line of contact, but in some cases a much greater amount of damage has resulted from the intrusion of the volcanic rock. Thus Professor David found that in places in the Stockton Mine, Newcastle, the Bore-hole seam had been much cindered by the dolerite, and he also reported that the Lower Tomago seams have suffered considerably from the same cause at Hexham and Ash Island, being converted into natural coke or completely cindered in places.

It is in the Southern Coal-field, however, that the greatest effect of volcanic intrusions upon the coal seams is noticeable, and this fact is no doubt due to the greater size of the dykes intersecting this field, and its proximity to the old centre of volcanic activity. Near Bulli dolerite dykes of great width (up to 100 yards in some cases) can be seen at the surface and the colliery workings have proved that offshoots from these dykes, in the shape of horizontal sheets, have followed the coal seams for considerable distances, with the result that large areas of coal have been converted into natural coke. In some instances there has been a good sale for this natural coke, at a satisfactory price, for fuel; but, on the whole, there can be no doubt that the effect of the volcanic intrusions near Bulli has been very detrimental.

*Continuation of the Permo-Carboniferous Coal Measures under Sydney.*—The late Rev. W. B. Clarke was the first to argue, on scientific evidence, the probable occurrence of coal under Sydney. In the year 1847 he made the following statement in his evidence before a Select Committee of the Legislative Council on Coal Inquiry:—"If we take a dip of only 1° from Newcastle to the south, and from Illawarra to the north, the synclinal curve will meet at the entrance to Broken Bay, which is exactly half-way (the extremity probably of the minor axis), at a depth of 4,680 feet, the depth of the coal seams if continuous."

The late Mr. Wm. Keene, Examiner of Coal-fields, as well as Mr. John Mackenzie, his successor in office, both subsequently supported the same argument, as did Mr. C. S. Wilkinson, late Geological Surveyor-in-Charge. Finally, Mr. Robert Etheridge, junior, and Professor David advanced the opinion that the Illawarra Coal Measures were the equivalents of the Newcastle Measures, and inferred that the Bulli seam of the Illawarra Field was identical with the Wallarah seam of Lake Macquarie. Mr. Etheridge's opinion was based upon palæontological evidence alone, while Professor David's views were the outcome of his work in the field.

For many years past, therefore, there has been no doubt in the minds of local geologists as to the coal measures of the Newcastle and Illawarra fields being continuous under Sydney, and the only question upon which there was any divergence of opinion was as to the actual depth at which the coal would be found to occur. This question of depth was, however, one of considerable importance from a commercial point of view, since it was quite possible that the depth of the coal under the metropolitan area would be too great to allow of its profitable extraction, and the Rev. W. B. Clarke's estimate (already alluded to), on the basis of a regular dip of only 1° from Newcastle and Illawarra respectively towards the centre of the basin, indicated a depth of 4,680 feet to the coal under Broken Bay.

Obviously the problem could be most easily solved by boring, and the first attempt in this direction was made in 1878, when a diamond drill bore was put down at Newington, on the Parramatta River. This bore attained a depth of 1,312 feet, without striking coal, and was then abandoned. In the following year another bore, put down at Botany, reached a depth of 2,193 feet, when it also was abandoned without accomplishing its object. The third attempt was made at Moore Park, where, at a depth of 1,860 feet, the bore was abandoned without having reached the coal. Other unsuccessful bores were put down at Narrabeen, north of Manly, 1,985 feet, and at Rose Bay, Sydney Harbour, 1,700 feet, the cause of failure in each case being the fact that a sufficient depth was not attained.

In 1884, a bore at Camp Creek, near the site where the Metropolitan Colliery's shaft was subsequently sunk, was successful in striking the Bulli seam, 12 feet thick, at a depth of 846 feet from the surface.

In 1886 a bore was put down near the Waterfall Railway Station, to a depth of 1,586 feet, and two seams of coal were reached, viz., an upper seam, 4 feet 8½ inches thick, at a depth of 1,513 feet, and a lower seam, 6 feet 1 inch thick, at a depth of 1,577 feet from the surface.

In 1887 another successful bore was completed, this time at Dent's Creek, on the Holt–Sutherland Estate. The total depth reached was 2,307 feet from the surface, and two seams of coal were again penetrated, viz., an upper seam, 4 feet 2 inches thick, at a depth of 2,228 feet, and a lower seam, 5 feet 3 inches thick, at 2,296 feet from the surface.

Again, at Moorebank, near Liverpool, a bore was carried to a depth of 2,601 feet, and penetrated three seams of coal; the upper seam, 1 foot 5 inches thick, was met with at 2,493 feet; the second, 1 foot 4 inches thick at 2,507 feet; and the lowest, 6 feet 6 inches thick at 2,583 feet from the surface.

The Liverpool bore was situated at a distance of twenty miles south-west of Sydney, while the Holt-Sutherland bore was only about fifteen miles in a direction rather west of south from the City, so that the evidence afforded by them went a long way in support of the theory of the continuity of the Newcastle and Illawarra coal measures, though it did not absolutely demonstrate it.

The opinion was formed that the comparatively thin seams met with in the Liverpool and Holt-Sutherland bores were the result of a splitting up of the thick (Bulli) seam penetrated at Camp Creek, and it was believed that these seams would reunite as they were traced further to the north, a belief which was subsequently confirmed.

In 1890, a party of gentlemen who had applied for the right to mine for coal beneath Sydney Harbour, deemed it advisable to place the question (of the occurrence of coal there) beyond all doubt before forming a company, to erect the necessary plant, and sink the shafts. They accordingly put down a diamond drill bore on Cremorne Point, on the northern shore of the harbour, and in 1891 this bore was completed at a depth of 3,095 feet. At 2,801 feet a seam of coal 7 ft. 4 in. thick was penetrated, but unfortunately the site had been chosen close to the outcrop of a dolerite dyke which had intruded the seam just where the drill penetrated it, and consequently the coal was found to be charred, or partly converted into coke, by the action of the molten rock. It was then decided not to endeavour to float the company until a sample of good coal from the seam could be exhibited, and it consequently became necessary to put down a second bore. The Government of the day regarded the experiment as one of almost national importance, as the future value to the Colony of workable seams of coal beneath Sydney could scarcely be over-estimated; they therefore acceded to a request for assistance made by the syndicate, and granted a sum of money from the Prospecting Vote to cover part of the expense of putting down a second bore at Cremorne. The site for the second bore was chosen as far away as possible from the outcrops of dolerite dykes, and boring operations were commenced in July, 1892, under the supervision of Mr. W. H. J. Slee, Superintendent of Diamond Drills. On the 9th November, 1893, the drill penetrated a fine seam of coal, 10 ft. 3 in. thick, and free from any alteration by contact with dykes. The depth of the bore from the surface (143 feet above sea level) to the roof of the coal seam, was 2,917 feet. The following is a descending section of the seam :—

| Roof, clay shale. | ft. | in. |
|---|---|---|
| Coaly clay shale ... ... ... ... ... | 0 | 1 |
| Splint coal, somewhat inferior ... ... ... | 0 | 8 |
| Coal, splint and bituminous, of good quality ... | 2 | 10 |
| Band, dark clay shale ... ... ... ... | 0 | $\frac{1}{4}$ |
| Coal, splint and bituminous, of good quality ... | 6 | $4\frac{1}{4}$ |
| Coal, soft, bituminous, a trifle clayey ... ... | 0 | $3\frac{1}{2}$ |
| | 10 | 3 |

Floor, black carbonaceous clay shale, containing impressions of *Vertebraria.*

Analyses were made, by Mr. J. C. H. Mingaye, of six samples taken from different portions of the core of coal brought up by the diamond

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drill. The mean of these six analyses gave the average composition of the entire seam as follows:—

| | | |
|---|---|---|
| Hygroscopic moisture ... ... | ·66 | |
| Volatile hydrocarbons ... ... | 17·57 | |
| Fixed carbon ... ... ... | 71·09 | Coke, 81·77 |
| Ash ... ... ... ... ... | 10·68 | |
| | 100·00 | |

Sulphur, ·724; Specific gravity, 1·346; calorimetric value, 13.

It is evident from these figures that the coal is of good quality, and especially suitable for steam-raising or smelting purposes.

The result of the boring operations at Cremorne established beyond all doubt the fact that the Newcastle and Illawarra Coal Measures are continuous under Sydney, and an enormous coal-bearing area, in which the coal occurs within a workable depth from the surface, is thus added to the already large reserves of the Colony. There is reason for believing that the Cremorne bore penetrated the basin at or near its deepest part, and that the Bulli seam, which is without doubt the one met with in this bore, will be found to rise gradually as it is traced further north and south, as well as east and west from Sydney.

It is not unreasonable to expect that several, if not all the other seams of the Newcastle Coal Measures will yet be found to occur within a workable depth from the surface under Sydney; the question as to whether the Middle or Tomago Coal Measures extend as far south as Port Jackson has not yet been definitely settled, as the Cremorne bore did not extend to a sufficient depth to intersect them, if present. There is no reason to doubt that the Lower or Greta Measures underlie Sydney, but their depth must be so great that there is very little probability of their ever being worked there.

The results obtained in the Cremorne bore led to the formation of the Sydney Harbours Collieries Company, who acquired an area of land at Long Nose Point, Balmain, for the purpose of sinking shafts and erecting a plant capable of working the coal under the waters of Port Jackson. The shafts will be about 2,800 feet deep, circular in form, with a diameter of eighteen feet, and lined throughout with brick-work; already one of them is nearing completion. The colliery is being equipped with the most modern machinery, including a Walker's fan, twenty-four feet in diameter, and eight feet in width, for ventilating the workings. The progress of the enterprise will be watched with much interest, for it must be remembered that the colliery will be amongst the deepest in the world. It is not anticipated that much trouble will be experienced in the matter of water, though it is probable that fire-damp will be met with; and again the question of pressure is one that will have to be considered, as these coal workings will be two and a half times as deep as any at present in existence in Australia. Nevertheless it is believed that the company will, under good management, be able to cope with any difficulties it may encounter, and that in a short time the largest ocean steamers will load their cargoes of coal from the colliery's wharf in Sydney.

As another example of an important colliery equipped with the most modern appliances for economical and efficient work, and for ensuring as far as possible the health and safety of the miners, the *Metropolitan Coal Company's Mine at Helensburgh* may be cited. This mine is situated close to the Illawarra railway line and is about twenty-seven miles south of Sydney. The area of the property is about 20,300 acres, of which 18,000 acres are Crown lands, the remaining 2,300 acres being leased from the private owner.

The coal seam which is being worked is known as the Bulli seam, and has a thickness of about eleven feet, with an inch band near the centre. Only the upper portion of the seam, having a thickness of six feet, is being extracted.

There are two circular shafts, each eleven hundred feet in depth; the main shaft has a diameter of sixteen feet, while the air shaft is one foot less in width.

The workings now extend for a total length of about three miles, by a maximum width of about three quarters of a mile; to the north of the main shaft they extend for two miles in a straight line.

The winding engines comprise two thirty-six inch cylinders of nine-hundred horse-power (indicated), and the time occupied in raising the cage from the bottom of the shaft to the surface, a vertical distance of eleven hundred feet, is twenty-eight seconds. The shaft is fitted with wire rope guides.

The ventilation of the mine is effected by a Schiele fan, having a diameter of twenty-feet, by a width of seven feet, and fitted with a Walker's shutter; it is driven at a velocity of 130 revolutions per minute, and provides a current of 350,000 cubic feet of air per minute, with a 4½ inch water gauge.

The colliery is equipped with three systems of endless-rope haulage, worked independently by three separate plants; the average speed maintained is from one to one and a quarter mile per hour. Self-acting inclines communicate between the endless-rope tramways and the working places.

The coal is wrought by excavating what are known as Welsh bords, leaving pillars which are subsequently extracted, allowing the roof to fall. The Welsh bords are ten yards in width, and the waste material is thrown into the centre, where it forms a wall or partition, which facilitates ventilation, and allows of a roadway at each side of the bord. It is usual to connect parallel bords with a cut-through every 100 yards, but frequently bords have been carried 300 yards without difficulty. The bords are separated by 50-yard pillars, but in some districts every

*Photographed by E. F. Pittman.*

THE METROPOLITAN COLLIERY HELENSBURGH.

third pillar is 100 yards in width. The usual practice now is to have large areas opened up by headings, but to form no pillars until those of the adjoining district have been extracted. This localises the effect of the weight of the cover.

The coal is a superior quality of steam coal, and is supplied to the Government railways and also to the navy. The output is about 1,000 tons per day, but this could be materially increased if sufficient labour were available. The coal requires no under-cutting, but comes down freely from the face when struck with the pick; it should, therefore, be very cheaply extracted.

The mine is a gassy one, and is subject to sudden outbursts of firedamp and crushed coal, especially along defined zones of disturbance; safety-lamps (of the Evans-Thomas pattern) are invariably used, but the ventilation of the colliery is so efficient that the danger from explosions of firedamp is reduced to a minimum.

*Quantity of coal available in New South Wales.*—Attempts to calculate the quantity of coal available in any large area of country are always more or less hazardous, as is proved by the wide margin of difference between the estimates, made by various authorities, of the quantity of coal remaining in the British coal-fields; and this is especially true in respect of a comparatively new country like Australia, where the exploratory workings, upon which such estimates must be largely based, are necessarily on a much smaller scale than in the case of Europe or America; nevertheless, even a very approximate valuation of our coal resources is of interest, more particularly on account of the rapidly-diminishing supplies, and continually increasing consumption of coal in the Old World.

Some years ago the late Mr. C. S. Wilkinson, Geological Surveyor-in-Charge, estimated that, within a depth of 4,000 feet from the surface, the New South Wales coal seams, of a thickness exceeding two and a half feet, are capable of producing 78,198,000,000 tons of coal, allowing one-fifth for loss in working.

Subsequently, in 1890, Professor David estimated that the unworked areas of the Palæozoic Coal-fields of New South Wales, contained between 130,000,000,000 and 150,000,000,000 tons of coal, assuming 4,000 feet to be the limit down to which coal can be profitably worked, and not taking into consideration seams of less than three feet in thickness. He also pointed out that the quantity quoted was more than equal to all the accessible unworked coal of Great Britain.

At the present time we are in possession of rather more accurate information in regard to the area of our coal-bearing lands, though there is still a great amount of uncertainty as to the average thickness of workable coal which may be expected to underlie them, and also as to the quality of the fuel under considerable tracts as yet unexplored.

For the purposes of an approximate estimate, however, we may assume the following :—

*Palæozoic Coal-fields.*

| | |
|---|---|
| Area within which the Upper and Middle Coal Measures are productive, within 4,000 feet of the surface ... | 15,800 square miles. |
| Area within which the Greta Coal Measures are productive, in the Northern district, within 4,000 feet of the surface... ... ... ... ... ... ... ... | 250 ,, ,, |
| Area within which the Greta Coal Measures are productive, in the Southern district, within 4,000 feet of the surface | 500 ,, ,, |
| Total Area ... ... ... ... ... | 16,550 square miles. |

In their most productive areas—

the Upper Coal Measures contain from 50 to 60 feet of workable coal ;
the Middle Coal Measures contain 20 feet of workable coal ;
the Greta Coal Measures contain from 20 to 40 feet of workable coal ;

so that there is a maximum thickness of about one hundred and twenty feet of workable coal in the Permo-Carboniferous rocks. It would, however, be very unsafe, in estimating our coal resources, to assume that anything approaching that thickness of coal is available under the area mentioned above ; for in the first place there are good reasons for believing that the Middle Coal Measures are not continuous for a very great distance, but that they thin out to the south of Newcastle ; then again, the Greta Coal Measures, though probably continuous under Newcastle and Sydney, must occur at too great a depth to allow of their being worked ; lastly, it is more than probable that, under considerable areas, a proportion of the coal in the Upper Coal Measures is of inferior quality.

It is therefore preferable to base the calculation upon the assumption that a thickness of only ten feet of workable coal underlies an area of 16,550 square miles. Taking 84 lb. as the weight of a cubic foot of coal, and deducting one-third of the gross weight for loss in working, impurities, &c., this would represent a total quantity of 115,346,880,000 tons of available fuel. If there should prove to be twenty feet in thickness of workable coal under the whole area instead of ten feet, then the above figures will have to be doubled ; but it is preferable, in view of the uncertainties of the case, to assume a thickness that appears to be reasonably safe.

In this calculation no account has been taken of the Triassic Coal Measures of the Clarence Basin, or of the area to the west of a line stretching from Dubbo to Texas. The coal in these Measures is probably suitable for use locally, but its quality is not sufficiently good for export purposes, and it would be expensive to work by reason of the numerous bands of shale which occur in the seams.

## Analyses of New South Wales Coals.

A large number of analyses of coal is on record of so-called "samples" from the Northern, Southern, and Western Coal-fields of New South

Wales, and it has been customary, in the past, to take the mean of these analyses as representing the average composition of the coal from the several fields. There is reason for believing, however, that these so-called samples were not, in many instances, truly representative of the various seams from which they were selected, many of them being single fragments taken from some particular band in which the coal presented a favourable appearance, and hence the results obtained probably indicated a better quality of coal than could be obtained in bulk from the seam.

The value of an analysis of a sample of coal depends mainly upon the manner in which the sample is taken, since the proportions of volatile hydrocarbons, fixed carbon, and ash, vary considerably in different parts of the same seam, and carelessly selected samples may give an absolutely misleading idea of the value of any seam for commercial purposes.

With the object, therefore, of obtaining, for publication in this volume, as reliable information as possible in regard to the average composition of the coal at present being worked in the different coal-mines of New South Wales, the Government Inspectors of Collieries were requested to take thoroughly representative samples, in the presence of the Managers, and forward them to the Department of Mines for analysis.

The following is a copy of the directions forwarded to each of the Inspectors:—

*Details to be observed in taking the samples of Coal for analysis.*

The samples should be taken from two of the working faces of the colliery as far from one another as possible. A strip of coal should be carefully cut out with a hammer and chisel for the whole thickness of the seam as worked, so that the sample may represent the coal actually sent to market. The strip of coal should be the same width (say three inches) all the way from the roof to the floor, and the depth of the cut should also be uniform. If any bands occur, which are usually picked out before the coal is sent to market, they should also be excluded from the sample, but all those which are usually left in the coal sent to market should also be included in the sample. Before taking a sample the floor of the working place should be cleared, and a clean sack or large piece of paper should be placed so as to catch all the coal cut out of the strip. The entire quantity should then be broken down carefully to the size of small nuts, and thoroughly mixed. One half of this should then be again well mixed and halved, and the mixing and halving should be continued until a sample of about a pound and a half in weight has been obtained. It is especially desired that the greatest care be observed in attending to all the above details.

The Inspectors were kind enough to exercise a considerable amount of trouble in carrying out this work, and the samples were then analysed in the Laboratory of the Department of Mines; it is believed, therefore, that the results may be regarded as trustworthy. They are appended in tabular form and include the analyses of seventy-seven samples of Northern coals, twenty-one samples of Southern, and thirteen samples of Western. The samples were taken in the year 1899.

*Proximate Analyses of Coals from the Northern Coal-fields.*

| Name of Colliery, Locality, Section of Seam, &c. | Section | Hygroscopic Moisture. | Volatile Hpdrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| Australian Agricultural Company's New Winning Colliery, Newcastle. Sample from extreme S.W. of the workings (Borehole Seam). Upper Coal Measures. | Section No. 1.<br>ft. in.<br>Top band coal 3 10<br>Stone band .. 0 1<br>Top coal .. 4 8<br>Morgan stone 0 7<br>Four-inch coal 0 10<br>Stone band .. 0 1<br>Little tops coal 1 0<br>Jerry stone .. 1 8<br>Bottom coal.. 3 0<br>15 9 | 1·57 | 36·97 | 55·11 | 6·35 | ·425 | 1·302 | 61·46 | 13·5 | Coke, well swollen, with cauliflower-like excrescences; firm and lustrous. Ash, reddish tinge; granular. |
| A.A. Company's New Winning or Sea Pit Colliery, Newcastle. Second sample taken at the extreme end of the workings. Section of seam same as above. | | 1·71 | 37·79 | 54·99 | 5·51 | ·412 | 1·293 | 60·50 | 13·7 | Do do |
| Sample from Bloomfield Colliery, East Maitland. Middle Coal Measures. | Section of seam.<br>ft. in.<br>Coal .. .. 1 8<br>Band .. 0 2<br>Coal . .. 1 8<br>Band .. .. 0 1<br>Coal parting.. 1 3<br>Coal .. .. 2 0<br>6 10 | 1·60 | 35·85 | 53·85 | 8·70 | 1·222 | 1·336 | 62·55 | 12·5 | Coke, fairly swollen; bright with dark patches; firm. Ash, reddish tint; flocculent. |

| Name of Colliery, Locality, Section of Seam, &c. | | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| Second sample from Bloomfield Colliery, East Maitland. | Section of seam.<br>ft. in.<br>Coal .. 1 7<br>Band .. 0 2<br>Coal .. 1 8<br>Band .. 0 0½<br>Coal .. 1 3<br>Band .. 0 0¼<br>Coal .. 2 0<br>6 8¾ | 1·90 | 35·70 | 52·65 | 9·75 | ·878 | 1·357 | 62·40 | 12·3 | Coke, well swollen, bright and firm. Ash, light gray; flocculent. |
| Sample from Brown's No. 2 Colliery, Minmi. Upper Coal Measures. | Section of seam.<br>ft. in.<br>Coal .. 1 2<br>Band .. 0 1<br>Coal .. 1 2<br>Band .. 0 0½<br>Coal 0 7<br>Band 0 3<br>Coal .. 0 9<br>4 0½ | 1·85 | 33·25 | 54·90 | 10·00 | ·508 | 1·361 | 64·90 | 12·6 | Coke, well swollen, hard and bright. Ash, grayish; part flocculent, part granular. |
| Second sample from Brown's No. 2 Colliery, Minmi. | Section o seam.<br>ft. in.<br>Coal .. 1 6<br>Band .. 0 1<br>Coal .. 1 5<br>Band .. 0 1<br>Coal .. 3 2<br>6 3 | 1·70 | 36·35 | 52·80 | 9·15 | ·466 | 1·378 | 61·95 | 12·5 | Coke, well swollen, bright with dark patches, some cauliflower-like excresences; firm. Ash, faint yellow tint; flocculent. |

| Name of Colliery, Locality, Section of Seam, &c. | | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| Sample from Brown's No. 4 Colliery, Minmi. Upper Coal Measures. | Section of seam. ft. in.<br>Coal 1 4<br>Band .. 0 1<br>Coal .. 1 6<br>Band .. 0 1<br>Coal .. 1 7<br>4 7 | 2·10 | 34·40 | 54·80 | 8·70 | ·370 | 1·351 | 63·50 | 12·4 | Coke, moderately swollen; bright, firm, some cauliflower-like excrescences. Ash, reddish tinge; granular. |
| Second sample from Brown's No. 4 Colliery, Minmi. | Section of seam. ft. in.<br>Coal .. 1 7<br>Band .. 0 1<br>Coal .. 1 6<br>Band .. 0 1<br>Coal .. 1 5<br>4 8 | 2·05 | 34·40 | 55·35 | 8·20 | ·425 | 1·330 | 63·55 | 12·6 | Coke, fairly swollen, bright, with dark patches; firm. Ash, reddish; flocculent. |
| Sample from Burwood Colliery, Lambton (Borehole Seam). From extreme south-west part of workings. Upper Coal Measures. | Section of seam. ft. in.<br>Coal .. 2 9<br>Band 0 1<br>Coal .. 2 0<br>Band .. 0 1<br>Coal .. 1 0<br>5 11 | 1·95 | 36·55 | 54·30 | 7·20 | ·450 | 1·299 | 61·50 | 13·2 | Coke, well swollen, hard and bright. Ash, brownish; granular. |
| Second sample from the Burwood Colliery. From the extreme north-east part of the workings. | Section of seam. ft. in.<br>Coal .. 2 8<br>Band .. 0 1<br>Coal .. 2 3<br>Band .. 0 1<br>Coal .. 1 3<br>0 4 | 1·65 | 35·85 | 56·10 | 6·40 | ·398 | 1·319 | 62·50 | 13·2 | Do do |

| Name of Colliery, Locality, Section of Seam, &c. | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| Sample from Centenary Colliery, Curlewis. Clear seam, full height, 6 feet. Upper Coal Measures (?) | 2·40 | 33·30 | 56·30 | 8·00 | ·453 | 1·378 | 64·30 | 12·0 | Coke, moderately swollen, bright and firm. Ash, white and granular. |
| Sample from the Co-operative Colliery, Newcastle. Upper Coal Measures. Section of seam (ft. in.): Coal .. 1 9; Band .. 0 1; Splint .. 0 3; Coal .. 1 5½; Band .. 0 1; Coal .. 2 5; total 6 0½ | 1·70 | 35·25 | 54·12 | 8·93 | ·480 | 1·338 | 63·05 | 13·0 | Coke, well swollen, with cauli-flower-like exerescenees; firm and lustrous. Ash, reddish tinge; granular. |
| Second sample from the Co-operative Colliery. Section of seam (ft. in.): Coal .. 1 10; Band 0 1; Coal . 1 6; Band .. 0 1; Coal .. 2 0; total 5 6 | 1·70 | 35·50 | 55·10 | 7·70 | ·590 | 1·305 | 62·80 | 13·3 | Coke, well swollen, firm and lustrous. Ash, reddish tinge; flocculent. |
| Sample from Duckenfield Colliery, Newcastle. Upper Coal Measures. Section of seam (ft. in.): Coal .. 1 9; Band 0 1; Coal .. 1 7; Band .. 0 1; Coal 1 3; total 4 9 | 2·61 | 34·44 | 53·91 | 9·04 | ·601 | 1·324 | 62·95 | 12·7 | Coke, well swollen, firm and lustrons. Ash, gray in colour; granular. |

| Name of Colliery, Locality, Section of Seam, &c. | Section of seam. | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| Second sample from Duckenfield Colliery. | ft. in.<br>Coal .. 1 6<br>Band .. 0 0½<br>Coal .. 1 4<br>Band .. 0 0½<br>Coal .. 1 6<br>4 5 | 2·00 | 34·78 | 51·99 | 11·23 | ·519 | 1·305 | 63·22 | 12·2 | Coke, well swollen, with cauliflower-like excrescences; firm and lustrous. Ash, reddish tinge; granular. |
| Sample from Dudley Colliery, Dudley. Upper Coal Measures. | ft. in.<br>Coal 2 6<br>Band .. 0 1<br>Coal 2 3<br>Band .. 0 0½<br>Coal .. 1 0<br>5 10½ | ·70 | 37·90 | 53·45 | 7·95 | ·247 | 1·310 | 61·40 | 12·6 | Coke, well swollen; bright with dark patches, firm. Some large cauliflower-like excrescences. Ash, reddish; flocculent. |
| Second sample from Dudley Colliery. | ft. in.<br>Coal .. 2 6<br>Band .. 0 1<br>Coal .. 2 0<br>Band .. 0 1<br>Coal .. 0 10<br>5 6 | ·87 | 36·88 | 52·65 | 9·60 | ·315 | 1·355 | 62·25 | 12·3 | Coke, well swollen; bright with dark patches; firm. Ash, reddish; granular, some portions flocculent. |
| Sample from Dulwich Colliery, near Singleton. The thickness of the seam wrought is 4 ft. 10 in., of which 3 ft. 6 in. is coal, the remaining 1 ft. 4 in. being bands. (Upper Coal Measures?) ... ... ... | | 1·85 | 39·40 | 51·15 | 7·60 | ·617 | 1·301 | 58·75 | 12·9 | Coke, fairly swollen; firm. Ash, light brown; flocculent. |
| Sample from East Greta Colliery, West Maitland. Lower seam, Lower Coal Measures. From No. 1 tunnel, No. 3 south level. Height of seam, 7 ft. 6 in. | | 1·78 | 40·62 | 51·94 | 5·66 | 1·222 | 1·289 | 57·60 | 13·7 | Coke, well swollen, with cauliflower-like excrescences; firm and lustrous. Ash, slight reddish tinge; granular. |

| Name of Colliery, Locality, Section of Seam, &c. | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| Second sample from East Greta Colliery. From No. 2 tunnel, No. 3 north level. Height of seam, 7 ft. 6 in. Lower Coal Measures ... ... ... ... ... | 1·75 | 40·28 | 52·57 | 5·40 | ·878 | 1·279 | 57·97 | 13·7 | Coke, well swollen, with cauliflower-like excrescences; firm and lustrous. Ash, slight reddish tinge; granular. |
| Sample from Ebbw Vale Colliery, New Lambton (Burwood Seam). Upper Coal Measures ... ... ... ... ... | 2·20 | 36·00 | 53·75 | 8·05 | ·343 | 1·349 | 61·80 | 12·6 | Coke, moderately swollen; bright and firm. Ash, light gray; flocculent. |
| Second sample from Ebbw Vale Colliery... | 2·25 | 35·40 | 51·95 | 10·40 | ·370 | 1·323 | 62·35 | 12·0 | Coke, fairly swollen; bright and firm, a few cauliflower-like excrescences. Ash gray; granular. |
| Sample from Elliott's Granbalang Colliery, Rix's Creek. Thickness of seam wrought is 8 ft. 9 in., of which 7 ft. 3 in. is coal, the remaining 1 ft. 6 in. being bands. (Upper Coal Measures ?) ... ... ... | 1·50 | 36·95 | 52·00 | 9·55 | ·672 | 1·300 | 61·55 | 12·9 | Coke, well swollen, bright and firm. Ash, brownish, part granular, part flocculent. |
| Sample from the Greta Colliery (Greta Seam). From Bartlett's district. Height of seam, 8 ft. 7 in. Lower Coal Measures ... .. ... ... ... | 1·55 | 39·74 | 49·91 | 8·80 | 1·410 | 1·310 | 58·71 | 13·4 | Coke, well swollen, with cauliflower-like excrescences; firm and lustrous. Ash, gray in colour; granular. |
| Second sample from Greta Colliery, Greta. From No. 3 district. Height of seam, 11 ft. 9 in. ... ... ... ... ... | 1·45 | 41·60 | 49·95 | 7·00 | 2·330 | 1·295 | 56·95 | 13·8 | Coke, well swollen, firm and good lustre. Ash, gray in colour; flocculent. |
| Sample from Gunnedah Colliery (Black Jack Mountain). Full height of seam, 6 ft., without a band. (Upper Coal Measures ?) ... ... ... ... ... | 2·55 | 35·35 | 55·35 | 6·75 | ·508 | 1·360 | 62·10 | 12·3 | Coke, not much swollen, hard and dull. Ash, grayish, part granular, part flocculent. |
| Sample from Hetton Colliery, Bullock Island, Newcastle. Upper Coal Measures. Section of seam: Coal 4 ft. 9 in.; Band 0 ft. 1 in.; Coal 5 ft. 0 in.; total 9 ft. 11 in. | 1·94 | 37·81 | 52·19 | 8·06 | ·287 | 1·299 | 60·25 | 13·3 | Excellent coke, well swollen, with cauliflower-like excrescences; firm and lustrous. Ash, slight reddish tinge; granular. |

| Name of Colliery, Locality, Section of Seam, &c. | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| Second sample from Hetton Colliery, Bullock Island ... ... ... ... | 1·88 | 37·01 | 55·87 | 5·24 | ·576 | 1·305 | 61·11 | 13·8 | Excellent coke as above. Ash, reddish tinge; flocculent. |
| Sample from Hillside Colliery, Waratah, Newcastle. (Burwood Seam). Upper Coal Measures ... ... ... ... | 2·10 | 33·75 | 53·30 | 10·85 | ·302 | 1·373 | 64·15 | 12·3 | Coke, fairly swollen, bright, with dark patches, some cauliflower-like excrescences. Ash, reddish tint; flocculent. |
| Second sample from the Hillside Colliery, Waratah ... ... ... ... ... | 2·05 | 33·65 | 55·60 | 8·70 | ·343 | 1·350 | 64·30 | 12·8 | Coke, not much swollen, hard and dull. Ash, grayish; part granular, part flocculent. |
| Sample from Inganee Colliery, Four-mile Creek, East Maitland. Middle Coal Measures. Section of seam. (ft. in.): Coal .. 3 4; Band 0 1; Coal 0 10; total 4 3 | 1·85 | 33·80 | 57·20 | 7·15 | ·521 | 1·328 | 64·35 | 12·5 | Coke, slightly swollen, bright and firm. Ash, reddish tint; flocculent. |
| Second sample from Inganee Colliery, Four-mile Creek. Section of seam. (ft. in.): Coal .. 3 5; Band .. 0 1; Coal .. 0 10; total 4 4 | 2·25 | 32·10 | 57·35 | 8·30 | ·740 | 1·351 | 65·65 | 12·0 | Coke, slightly swollen, bright and firm. Ash, faint yellow tinge; flocculent. |
| Sample from Johnson's Colliery, near Cardiff. Upper Coal Measures. (From the top of the Cardiff seam). Section of upper seam. (ft. in.): Coal .. .. 2 0; Stone band .. 0 1; Coal .. .. 2 8; Clay band 0 4; Coal .. . 2 0; total 7 1; Fireclay .. 6 0 | 3·35 | 29·55 | 48·85 | 18·25 | ·398 | 1·406 | ... | 11·1 | No coke formed, only a loosely coherent cake left after ignition. Ash, grayish colour; part granular, part flocculent. |

| Name of Colliery, Locality, Section of Seam, &c. | Section | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| Second sample from Johnson's Colliery. (From the lower portion of the seam). (Total thickness of coal and bands in upper and lower seams 14 ft. 2 in. There is a thickness of 6 feet of fireclay between the two seams.) | Section. ft. in.<br>Coal .. 1 2<br>Fireclay and coal, mixed 6 6<br>Coal and Stone band 0 9<br>Stone band .. 0 ½<br>Coal .. .. 0 9<br>Stone band .. 0 ½<br>Coal .. .. 2 6<br>Band .. .. 0 1<br>Coal .. .. 1 3<br>7 1 | 3·15 | 34·35 | 51·75 | 10·75 | ·398 | 1·330 | 62·50 | 12·2 | Coke, fairly swollen, dull and firm. Ash, grayish colour; part granular, part flocculent. |
| Sample from Killingworth Colliery, near Cockle Creek Station. Upper Coal Measures. | Section of seam. ft. in.<br>Coal 1 5<br>Band 0 ½<br>Coal .. 1 8<br>Band 0 ½<br>Coal 0 11<br>4 1 | 2·31 | 35·26 | 52·31 | 10·12 | ·453 | 1·312 | 62·43 | 13·6 | Coke, excellent, well swollen, with cauliflower-like excrescences, firm and lustrous. Ash, gray in colour; granular. |
| Second sample from Killingworth Colliery. | Section of seam. ft. in.<br>Coal 1 6<br>Band 0 0¾<br>Coal 1 8<br>Band .. 0 0½<br>Coal .. 1 0<br>4 3¼ | 2·04 | 35·60 | 53·26 | 9·10 | ·357 | 1·319 | 62·36 | 12·9 | Excellent coke, well-swollen, with cauliflower-like excrescences; firm and lustrous. Ash, gray in colour; flocculent. |

| Name of Colliery, Locality, Section of Seam, &c. | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| Sample from Lambton Colliery, Lambton. From Tunnel Flat, Borehole Seam. Height of seam, 8 ft. 11 in. Upper Coal Measures ... ... ... ... | 2·32 | 34·21 | 56·84 | 6·63 | ·329 | 1·329 | 63·47 | 13·3 | Coke, well-swollen, with cauliflower-like excrescences; firm and lustrous. Ash, reddish; granular. |
| Second sample from Lambton Colliery. From Far Flat District. Height of seam, 5 ft. 6 in. ... ... ... ... | 2·36 | 33·27 | 55·50 | 8·87 | ·672 | 1·359 | 64·37 | 12·5 | Coke, well-swollen, with cauliflower-like excrescences; firm and lustrous. Ash, slight reddish tinge; granular. |
| Sample from Lambton "B" Pit, late Durham Colliery. From east side of shaft, between shaft and sea-coast. Height of seam, about 5 feet, with two stone bands, each an inch in thickness. Upper Coal Measures ... ... ... | 1·65 | 34·50 | 54·75 | 9·10 | ·494 | 1·345 | 63·85 | 12·6 | Coke, fairly swollen; firm. Ash, light brown; flocculent. |
| Second sample from Lambton "B" Pit, taken about 50 yards from the first. Height of seam as above ... ... ... | 1·80 | 32·75 | 56·20 | 9·25 | ·480 | 1·343 | 65·45 | 12·8 | Do do |
| Sample from Marshall's Colliery, East Maitland. Middle Coal Measures. Section of seam. (ft. in.) Coal .. 1 0; Band .. 0 0½; Coal 3 4; Band .. 1; Coal .. 0 6; total 4 11½ | 2·15 | 33·90 | 56·35 | 7·60 | ·961 | 1·341 | 63·95 | 12·4 | Coke, fairly swollen; firm and lustrous. Ash, reddish; granular. |
| Sample from Maryland Colliery, Plattsburgh, Newcastle. Upper Coal Measures. Height of seam, 6 ft. 6 in. ... | 2·25 | 35·50 | 57·90 | 4·35 | ·562 | 1·299 | 62·25 | 13·7 | Coke, well swollen, firm and lustrous. Ash, buff-coloured; flocculent. |

| Name of Colliery, Locality, Section of Seam, &c. | Section of seam. | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| Second sample from Maryland Colliery, Plattsburg. | ft. in.<br>Coal .. 2 0<br>Band .. 0 1<br>Coal .. 4 2<br>6 3 | 2·25 | 35·90 | 56·60 | 5·25 | ·686 | 1·293 | 61·85 | 13·4 | Coke, well swollen, firm and lustrous. Ash, reddish tinge; flocculent. |
| Sample from Morrisett Colliery, Lake Macquarie. Upper Coal Measures. | ft. in.<br>Coal .. 3 5<br>Band .. 0 1<br>Coal .. 1 0<br>Band .. 0 0½<br>Coal .. 1 0<br>5 6½ | 2·10 | 27·20 | 55·85 | 14·85 | ·357 | 1·469 | ... | 11·0 | No coke formed, only a loosely coherent cake left after ignition. Ash, yellowish tinge; flocculent. |
| Second sample from Morrisett Colliery, Lake Macquarie. | ft. in.<br>Coal .. 3 3<br>Band 0 1<br>Coal 1 1<br>Band 0 0½<br>Coal .. 1 0<br>5 5½ | 1·40 | 30·50 | 54·90 | 13·20 | ·274 | 1·427 | .. | 11·6 | No coke formed, only a dull, loosely coherent cake left after ignition. Ash, yellowish; part flocculent, part granular. |
| Sample from Newcastle Colliery, Newcastle. "A" Pit. Upper Coal Measures ... ... ... ... ... | | 1·70 | 36·00 | 55·65 | 6·65 | ·535 | 1·309 | 62·30 | 13·4 | Coke, well swollen, hard and bright. Ash, brownish; granular. |
| Second sample from Newcastle Colliery. "B" Pit ... ... ... ... ... | | ·75 | 39·10 | 54·75 | 5·40 | ·343 | 1·308 | 60·15 | 12·7 | Coke, well swollen; lustrou with dark patches. Ash, reddish tinge; part granular, part flocculent. |

| Name of Colliery, Locality, Section of Seam, &c. | Section of seam | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| Sample from New Lambton Colliery, New Lambton. Taken in No. 6 district, at the southern end of the colliery. Upper Coal Measures. | Section of seam. ft. in.<br>Top coal .. 1 4<br>Bastard coal .. 0 2<br>Stooe band .. 0 1<br>Coal .. .. 2 0<br>Stone band .. 0 1<br>Coal .. .. 1 1<br>Morgan 0 7<br>Coal .. .. 0 6<br>5 10 | 1·76 | 36·61 | 51·01 | 10·62 | ·466 | 1·300 | 61·63 | 12·8 | Coke, well swollen, with cauliflower-like excrescences; firm and lustrous. Ash, reddish tinge; granular. |
| Second sample from New Lambton Colliery. Taken in No. 6 District, at the extreme north of the colliery. | Section of seam. ft. in.<br>Top coal . 1 4<br>Bastard coal.. 0 4<br>Stone band .. 0 1<br>Coal .. .. 2 2<br>Stone band .. 0 1<br>Coal .. 0 10<br>Morgan .. 0 9<br>Coal .. . 0 6<br>6 1 | 1·84 | 35·68 | 53·46 | 9·02 | ·480 | 1·354 | 62·48 | 13·0 | Coke, well swollen, with cauliflower-like excresoences, firm and lustrous; ash, reddish tinge, granular. |
| Sample from New Park Colliery, Rix's Creek. Taken from No. 1 tunnel. The thickness of the seam is 8 ft. 6 in., of which 6 ft. 10 in. is coal, the remaining 1 ft. 8 in. being bands. Upper Coal Measures (?) ... ... ... ... | | 1·85 | 37·15 | 53·00 | 8·00 | ·617 | 1·206 | 61·00 | 12·7 | Coke, well swollen, bright and firm; ash, brownish, part granular, part flocculent. |
| Second sample from New Park Colliery. Taken from No. 2 tunnel. The thickness of the seam here is 8 ft. 11½ in., of which 6 ft. 1¼ in. is coal, the remaining 2 ft. 10¼ in. being bands ... ... | | 1·55 | 34·55 | 54·30 | 9·60 | ·645 | 1·313 | 63·90 | 12·4 | Coke, well swollen, bright and firm; ash, grayish, part granular, part flocculent. |

| Name of Colliery, Locality, Section of Seam, &c. | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| Sample from the Northern Extended Colliery, Teralba (Northern Seam). Taken from the west side. Upper Coal Measures ... ... ... ... ... | 2·20 | 31·40 | 53·74 | 12·66 | ·362 | 1·402 | 66·40 | 11·8 | Coke, not much swollen, fairly brittle and dull; ash, reddish tinge, flocculent. |
| Second sample from the Northern Extended Colliery, Teralba (Northern Seam). Taken from the east side ... | 1·90 | 33·67 | 53·65 | 10·78 | ·384 | 1·397 | 64·43 | 12·5 | Coke, not much swollen, brittle and dull; ash, reddish tinge, granular. |
| Sample from the Northumberland Colliery, Fassifern (Northern Seam). Taken from the east side of the workings. Height of seam, 7 ft. 6 in. Upper Coal Measures. | 2·44 | 31·76 | 49·70 | 16·10 | ·425 | 1·386 | ... | 11·6 | No true coke formed; ash, gray, flocculent. |
| Second sample from the Northumberland Colliery, Fassifern (Northern Seam). Taken from the west side of the workings. Height of seam, 8 feet ... ... | 2·65 | 29·32 | 51·69 | 16·34 | ·480 | 1·439 | ... | 11·3 | Do do |
| Sample from the Pacific Colliery, Teralba (Northern Seam). Taken from the west side of the mine. Height of seam, 7 ft. 10 in. Upper Coal Measures ... ... | 3·22 | 32·11 | 50·84 | 13·83 | ·395 | 1·421 | 64·67 | 11·7 | Coke, well swollen, fairly firm and lustrous; ash, gray, granular. |
| Second sample from the Pacific Colliery, Teralba (Northern Seam). Taken from the east side of the mine. Height of seam, 7 ft. 7 in. ... ... ... ... | 3·20 | 32·02 | 53·66 | 11·12 | ·450 | 1·390 | 64·78 | 12·0 | Do do |
| Sample from Rosedale Colliery, near Singleton. The thickness of the seam is 5 ft. 4 in., of which 4 ft. 5 in. is coal, the remaining 11 inches being bands. Upper Coal Measures (?)... ... ... | 1·85 | 37·75 | 53·90 | 6·50 | ·576 | 1·299 | 60·40 | 12·9 | Coke, fairly swollen, firm; ash, dark brown, flocculent. |

| Name of Colliery, Locality, Section of Seam, &c. | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| Sample from Seaham Colliery, West Wallsend. Lower Coal Measures. Section of seam (ft. in.): Coal .. 0 6; Band .. 0 0½; Coal .. 1 5½; Band .. 0 0½; Coal .. 1 7; Band 0 0½; Coal .. 1 4½; total 5 0½ | 1·95 | 33·85 | 51·20 | 13·00 | ·480 | 1·365 | 64·20 | 12·1 | Coke, fairly swollen, bright and firm; ash, reddish, granular. |
| Second sample from Seaham Colliery. Section of seam (ft. in.): Coal .. 0 5½; Band .. 0 0½; Coal .. 1 6; Band .. 0 1; Coal .. 1 7; Band .. 0 0½; Coal .. 1 4; total 5 0½ | 1·35 | 35·10 | 51·85 | 11·70 | ·466 | 1·402 | 63·55 | 12·5 | Do do |
| Sample from the South Greta Colliery (Lower Coal Measures, Lower Seam). Taken from the north side of the workings, where the thickness of the seam is 4 ft. 2 in. ... ... ... ... ... | 1·85 | 38·25 | 50·40 | 9·50 | ·851 | 1·335 | 59·90 | 13·0 | Coke, slightly swollen, bright and firm. Ash, slightly yellow, granular. |
| Second sample from the South Greta Colliery. Taken from the south side of the workings, where the thickness of the seam is 4 ft. 4 in. ... ... ... ... | 2·10 | 36·10 | 55·30 | 6·50 | ·878 | 1·331 | 61·80 | 12·8 | Coke, slightly swollen, bright and firm. Ash, reddish, granular. |

| Name of Colliery, Locality, Section of Seam, &c. | Section of seam. | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| Sample from the South Hetton Colliery, Toronto. Upper Coal Measures. | ft. in.<br>Coal 3 4<br>Band 0 1<br>Coal .. 3 4<br>6 9 | 2·17 | 31·33 | 56·95 | 9·55 | ·329 | 1·379 | ... | 12·3 | No coke formed, only a dull, loosely-cohering cake left after ignition. Ash granular. |
| Sample from Stockton Colliery, near Newcastle. Upper Coal Measures. | ft. in.<br>Coal .. 3 8<br>Band .. 0 1<br>Coal 3 1<br>Band 0 1<br>Coal .. 0 11<br>7 10 | 1·90 | 36·45 | 52·40 | 9·25 | ·233 | 1·302 | 61·65 | 12·5 | Coke, well swollen, bright, with dark patches, firm. Ash, reddish, flocculent. |
| Second sample from Stockton Colliery. | ft. in.<br>Coal 3 8<br>Band 0 1<br>Coal .. 3 0<br>6 9 | 1·00 | 37·25 | 53·10 | 8·65 | ·425 | 1·315 | 61·75 | 12·5 | Coke, well swollen, bright, with dark patches, a few large cauliflower-like excrescences, firm. Ash, yellowish, flocculent. |
| Sample from Thornley Colliery, East Maitland. Middle Coal Measures. | ft. in.<br>Coal 3 5<br>Band 0 1<br>Coal .. 0 6<br>4 0 | 1·90 | 34·15 | 57·40 | 6·55 | ·576 | 1·391 | 63·95 | 12·7 | Coke, moderately swollen, bright, firm. Ash, yellowish tint, flocculent. |

| Name of Colliery, Locality, Section of Seam, &c. | | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| Second sample from Thornley Colliery, East Maitland. | Section of seam. ft. in.<br>Coal .. 3 6<br>Band .. 0 1<br>Coal .. 0 8<br>4 3 | 1·20 | 35·50 | 56·75 | 6·55 | ·466 | 1·332 | 63·30 | 12·5 | Coke, fairly swollen, bright and firm. Ash, yellowish, flocculent. |
| Sample from Wallarah Colliery, Swansea. Upper Coal Measures. | Section of seam. ft. in.<br>Coal .. 6 0 | 1·20 | 31·85 | 57·70 | 9·25 | ·343 | 1·391 | ... | 12·3 | No true coke formed, only a dull, loosely-coherent cake left after ignition. Ash, yellowish, granular. |
| Second sample from Wallarah Colliery, Swansea. | Section of seam. ft. in.<br>Coal .. 3 6<br>Band .. 0 0½<br>Coal .. 2 10<br>6 4½ | ·75 | 33·50 | 57·20 | 8·55 | ·302 | 1·375 | ... | 12·3 | No coke formed, only a dull, loosely-coherent cake left after ignition. Ash, yellowish, part flocculent, part granular. |
| Sample from Wallsend No. 2 Colliery, Wallsend. Upper Coal Measures. | Section of seam. ft. in.<br>Coal .. 2 6<br>Band .. 0 1<br>Coal .. 1 11<br>Band .. 0 1<br>Coal .. 1 8<br>Jerry .. 0 3<br>Coal .. 2 4<br>8 10 | 2·46 | 33·45 | 56·04 | 8·05 | ·343 | 1·295 | 64·09 | 13·0 | Excellent coke, well swollen, with cauliflower-like excrescences, firm and lustrous. Ash, slight reddish tinge, flocculent. |
| Second sample from Wallsend No. 2 Colliery. | Section of seam. ft. in.<br>Coal .. 2 8<br>Band .. 0 1<br>Coal .. 2 3<br>Band .. 0 1<br>Coal .. 3 6<br>8 7 | 2·45 | 33·40 | 56·45 | 7·70 | ·699 | 1·306 | 64·15 | 13·4 | Coke, well swollen, with cauliflower-like excrescences, firm and lustrous. Ash, reddish tinge, flocculent. |

| Name of Colliery, Locality, Section of Seam, &c. | Section of seam. | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| Sample from Waratah Colliery, Charlestown. Upper Coal Measures. Taken three-quarters of a mile south-east of main shaft. | Section of seam.<br>ft. in.<br>Coal .. 1 11<br>Stone band .. 0 1<br>Coal .. .. 1 11<br>Stone band .. 0 1<br>Coal .. .. 0 10½<br>Morgan .. 0 6<br>Coal .. 0 7½<br>Stone band .. 0 1<br>Coal .. 0 11<br>7 0 | 1·85 | 32·90 | 55·95 | 9·30 | ·439 | 1·360 | 65·25 | 12·7 | Coke, well swollen, and firm. Ash, brownish, flocculent. |
| Second sample from Waratah Colliery, Charlestown. Taken one mile from the pit bottom. | Section of seam.<br>ft. in.<br>Coal .. 1 3½<br>Myrtle coal (impure) .. 0 3<br>Stone band .. 0 1<br>Coal .. 2 0½<br>Stone band .. 0 1<br>Coal .. 0 10½<br>Morgan 0 8½<br>Coal .. .. 0 7<br>Stone band .. 0 1<br>Coal .. .. 0 10<br>6 10 | 1·90 | 32·85 | 55·15 | 10·10 | ·453 | 1·332 | 65·25 | 12·6 | Coke, as above. |
| Sample from West Wallsend Colliery, Charlestown. Upper Coal Measures. | Section of seam.<br>ft. in.<br>Coal .. 1 6½<br>Band .. 0 0¾<br>Coal . 1 7<br>Band .. 0 0¾<br>Coal .. 1 5<br>4 8 | 1·55 | 35·45 | 53·15 | 9·85 | ·603 | 1·357 | 63·00 | 12·5 | Coke, not much swollen, bright, firm and covered with cauliflower-like excrescences. Ash, reddish, granular. |

| Name of Colliery, Locality, Section of Seam, &c. | Section of seam. | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| Second sample from West Wallsend Colliery, Charlestown. | ft. in.<br>Coal .. 1 6<br>Band .. 0 0¾<br>Coal .. 1 6<br>Band .. 0 0½<br>Coal .. 1 3½<br>4 4¾ | 1·60 | 36·20 | 53·95 | 8·25 | ·466 | 1·374 | 62·20 | 12·8 | Coke, moderately swollen, bright in patches, firm. Ash, reddish, granular. |
| Sample from Wickham and Bullock Island Colliery, Newcastle. Upper Coal Measures. | ft. in.<br>Coal .. 1 3<br>Band .. 0 1<br>Dirt .. 0 9<br>Co .. 3 9<br>5 10 | 1·83 | 36·95 | 55·61 | 5·61 | ·494 | 1·289 | 61·22 | 13·5 | Coke, well swollen, with cauliflower-like excrescences, firm and lustrous. Ash, reddish tinge, granular. |
| Second sample from Wickham and Bullock Island Colliery. | ft. in.<br>Coal .. 3 3<br>Band .. 0 1<br>Coal .. 1 8<br>Morgan 1 1<br>Coal .. 0 6<br>Band .. 0 1<br>Coal .. 1 1<br>Jerry .. 0 9<br>Coal .. 3 7<br>12 1 | 1·59 | 39·25 | 54·68 | 4·48 | ·439 | 1·283 | 59·16 | 14·0 | Coke, as above. |

The average composition of the coal from the collieries of the Northern Coal-fields, as calculated from the above seventy-seven analyses, is as follows :—

| | |
|---|---|
| Hygroscopic moisture | 1·92 |
| Volatile hydrocarbons | 35·09 |
| Fixed carbon | 54·08 |
| Ash | 8·91 |
| | 100·00 |

Sulphur ........ ·541

Proximate Analyses of samples of coal from the Collieries of the Southern Coal-field. These coal-seams are all in the Upper Coal Measures (Permo-Carboniferous).

| Name of Colliery, Locality, Section of Seam, &c. | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| Sample from Bellambi Colliery. (Top Seam.) Taken from "the Straight Down." Height of seam, 7 feet. ... | ·72 | 24·92 | 64·35 | 10·01 | ·658 | 1·377 | 74·36 | 12·7 | Coke, well swollen, fairly firm, and lustrous. Ash, gray, flocculent. |
| Second sample from the Bellambi Colliery. (Top Seam.) Taken from No. 4 district. Height of seam, 8 feet. ... ... ... | ·85 | 23·68 | 64·52 | 10·95 | ·549 | 1·400 | 75·47 | 13·4 | Coke, well swollen, firm and lustrous. Ash, gray, flocculent. |
| Sample from Brownlee's Prospecting Coal-mine, 9 miles west of Albion Park, Illawarra railway line. Taken from adit driven in about 150 yards from the mountain side. ... ... ... ... | 1·35 | 22·64 | 60·09 | 15·92 | ·576 | 1·428 | 76·01 | 11·3 | Coke, not much swollen, firm, dull. Ash, light gray, part granular, part flocculent. |
| Sample from Brownlee's No. 2 Coal-mine, 18 chains due west from No. 1 adit; about 9 miles west of Albion Park, Illawarra railway line. ... .. ... | 1·19 | 22·75 | 59·17 | 16·89 | ·562 | 1·431 | 76·06 | 11·3 | Coke, not much swollen, firm, dull. Ash, light gray, part granular, part flocculent. |
| Sample from Bulli Colliery. (Top Seam). Taken from Cox's district. Height of seam, 7 feet. ... ... ... ... | ·82 | 23·89 | 64·69 | 10·62 | ·658 | 1·404 | 75·58 | 13·2 | Coke, well swollen, with slight cauliflower-like excrescences, firm and lustrous. Ash, gray, flocculent. |
| Second sample from the Bulli Colliery. (Top Seam.) Taken from the Hill End district. Height of seam, 7 feet. ... | ·65 | 23·70 | 65·24 | 10·41 | ·672 | 1·400 | 75·65 | 13·3 | Coke, well swollen, with slight cauliflower-like excrescences, firm and lustrous. Ash, gray, flocculent. |
| Third sample from the Bulli Colliery. (Second, or Four-foot Seam.) Taken from the main heading. Height of seam, 4 feet. | ·82 | 21·90 | 65·82 | 11·46 | ·453 | 1·400 | 77·28 | 12·9 | Coke, well swollen, with cauliflower-like excrescences, firm and lustrous. Ash, gray, flocculent. |

| Name of Colliery, Locality, Section of Seam, &c. | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| Sample from Coalcliff Colliery. (Top Seam.) Taken from the railway heading. Height of seam, 5 feet ... ... ... ... | ·85 | 21·62 | 64·07 | 13·46 | ·274 | 1·402 | 77·53 | 12·5 | Coke, well swollen, with slight cauliflower-like excrescences, firm and lustrous. Ash, gray, flocculent. |
| Second sample from Coalcliff Colliery. Height of seam, 5 feet ... ... ... | ·80 | 21·52 | 65·54 | 12·14 | ·329 | 1·371 | 77·68 | 12·5 | Coke, as above. Ash, ditto. |
| Sample from Corrimal Colliery. Taken from main south heading. (Top Seam.) Height of seam, 6 ft. 9 in. ... ... | 1·13 | 24·57 | 64·85 | 9·45 | ·230 | 1·386 | 74·30 | 12·5 | Coke, well swollen, bright and firm. Ash, gray, flocculent. |
| Second sample from Corrimal Colliery. (Top Seam.) Taken from No. 3 left. ... | 1·13 | 25·02 | 64·75 | 9·10 | ·410 | 1·384 | 73·85 | 13·1 | Coke, well swollen, bright and firm. Ash, almost white, flocculent. |
| Sample from the Metropolitan Colliery, Helensburgh. (Top Seam.) Taken from the north jig. Height of seam, 11 ft.; only upper half worked ... ... ... | 1·40 | 18·26 | 70·29 | 10·05 | ·398 | 1·408 | 80·34 | 12·5 | Coke, of poor quality, not much swollen, fairly brittle, and dull. Ash, slight, reddish tinge, granular. |
| Second sample from the Metropolitan Colliery. (Top Seam.) Taken from the back heading. Height of seam, 11 ft.; only upper half worked ... ... ... | 1·15 | 18·54 | 70·83 | 9·48 | ·370 | 1·396 | 80·31 | 13·2 | Coke, not much swollen, dull lustre, and fairly brittle. Ash, slightly reddish tinge, granular. |
| Sample from the Mount Pleasant Colliery, Wollongong. (Top Seam.) Taken from the left-hand district ... ... ... | 1·10 | 24·50 | 65·40 | 9·00 | ·370 | 1·371 | 74·40 | 13·4 | Coke, well swollen, with cauliflower-like excrescences, firm and lustrous. Ash, gray, granular. |
| Second sample from the Mount Pleasant Colliery. (Top Seam.) Taken from the main district ... ... ... ... | ·80 | 23·51 | 65·70 | 9·99 | ·340 | 1·385 | 75·69 | 12·6 | Coke, fairly well swollen, firm and lustrous. Ash, gray, granular. |
| Sample from the Osborne Wallsend Colliery, Wollongong. (Top Seam.) Taken from the straight down. Height of seam, 6 ft. 6 in. ... ... ... ... | ·90 | 23·93 | 65·02 | 10·15 | ·466 | 1·362 | 75·17 | 12·6 | Coke, well swollen, with slight cauliflower-like excrescences, firm, and lustrous. Ash, slight reddish tinge, flocculent. |

| Name of Colliery, Locality, Section of Seam, &c. | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | pecific Gravity. | Coke. | Lb. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| Second sample from the Osborne Wallsend Colliery. (Top Seam.) Taken from No. 4 heading. Height of seam, 7 feet. | ·97 | 24·56 | 65·11 | 9·36 | ·466 | 1·382 | 74·47 | 13·4 | Coke, well swollen, with slight cauliflower-like excrescences, firm and fairly lustrous. Ash, gray, flocculent. |
| Sample from the South Bulli Colliery, Bellambi. (Top Seam.) Taken from the north-west district ... ... ... | 1·00 | 25·40 | 66·00 | 7·60 | ·530 | 1·353 | 73·60 | 13·0 | Coke, well swollen, with cauliflower-like excrescenoes, firm and lustrous. Ash, yellowish tinge, flocculent. |
| Second sample from the South Bulli Colliery. (Top Seam.) Taken from the south-west district ... ... ... | ·78 | 24·92 | 65·25 | 9·05 | ·550 | 1·369 | 74·30 | 12·6 | Coke, well swollen, firm, and lustrous. Ash, very light gray, flocculent. |
| Sample from the South Clifton Colliery, Clifton. (Top Seam.) Taken from the Southern district. Height of seam, 4 ft. 3 in. .. ... ... ... ... | 1·00 | 21·80 | 66·75 | 10·45 | ·390 | 1·395 | 77·20 | 12·2 | Coke fairly swollen, bright and firm. Ash, slight reddish tinge, flocculent. |
| Second sample from the South Clifton Colliery. (Top Seam.) Taken from the Western district. Height of seam, 4 ft. 6 in. ... ... ... ... ... | ·93 | 23·57 | 67·00 | 8·50 | ·450 | 1·372 | 75·50 | 13·1 | Coke, well swollen, bright and firm. Ash, slight reddish tinge, flocculent. |

The average composition of the coal from these collieries of the Southern Coal-field, as calculated from the above twenty-one analyses, is as follows :—

| | |
|---|---|
| Hygroscopic moisture | ·97 |
| Volatile hydrocarbons | 23·10 |
| Fixed carbon | 65·26 |
| Ash | 10·67 |
| Sulphur, ·462. | |
| | 100·00 |

Proximate analysis of samples of Coal from the Collieries of the Western Coalfield. These coal seams are all in the Upper Coal Measures (Permo-Carboniferous).

| Name of Colliery, Locality, &c. | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbons. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lbs. of Water converted into steam by 1 lb. of the Coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| Sample from the Black Diamond Colliery, Blackman's Flat, Wallerawang ... | 1·85 | 33·55 | 46·65 | 17·95 | ·658 | 1·458 | 64·60 | 11·0 | Coke, not much swollen, fairly bright, firm, covered with cauliflower—like excrescences. Ash, white, granular. |
| Sample from the Cobar Copper Works Colliery, Lithgow ... ... .. | 1·95 | 30·50 | 51·65 | 15·90 | ·590 | 1·422 | ... | 11·3 | No coke formed; only a partially fritted cake left after ignition. Ash, almost white, granlar. |
| Sample from the Cullen-Bullen Colliery, Cullen Bullen ... ... ... ... | 1·25 | 34·15 | 51·95 | 12·65 | ·645 | 1·348 | 64·60 | 12·1 | Coke not much swollen, fairly bright, firm, covered with cauliflower-like excrescences. Ash, white, granular, with some flocculent patches. |
| Sample from the Eskbank Colliery, near Lithgow Taken from the East-dip ... | 1·07 | 33·38 | 52·80 | 12·75 | ·370 | 1·366 | 65·55 | 12·1 | Coke, very little swollen, bright and firm. Ash, very light grey, granular. |
| Sample from the Folly Colliery, Lidsdale, Wallerawang ... ... ... ... | 1·52 | 27·98 | 53·60 | 16·90 | ·892 | 1·422 | ... | 11·1 | No coke formed, only a fairly firm cake left after ignition. Ash, grayish, granular. |
| Sample from the Irondale Colliery, about one mile from Piper's Flat Station, Mudgee Railway Line ... ... ... | 3·95 | 26·17 | 55·25 | 14·63 | ·590 | 1·508 | ... | 11·4 | No true coke formed, mass fritted together, dull lustre. Ash, nearly white, granular. |
| Sample from the Ivanhoe Colliery, near Piper's Flat Station ... ... ... | 3·95 | 26·11 | 56·01 | 13·93 | ·580 | 1·400 | ... | 11·2 | Do do |

| Name of Colliery, Locality, Section of Seam, &c. | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Coke. | Lbs. of water converted into steam by 1 lb. of the coal. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| Sample from the Lithgow Valley Colliery, Lithgow ... ... ... ... ... | 2·25 | 33·20 | 53·35 | 11·20 | ·713 | 1·358 | ... | 12·1 | No coke formed, only a well fritted cake left after ignition. Ash, reddish tint, part granular, part flocculent. |
| Sample from the Oakey Park Colliery. Taken from No. 1 Right Division | 1·90 | 33·80 | 53·15 | 11·15 | ·830 | 1·278 | 64·30 | 12·6 | Coke, fairly swollen, lustrous and firm, numerous cauliflower-like excrescences. Ash, white, granular. |
| Sample from the Retort Colliery, Hartley Vale ... ... ... ... ... | 1·57 | 27·38 | 56·05 | 15·00 | ·603 | 1·416 | ... | 11·0 | No coke formed, only a fairly firm cake left after ignition. Ash, white, granular. |
| Sample from the Vale Colliery ... ... | 1·20 | 34·10 | 49·70 | 15·00 | ·521 | 1·361 | 64·70 | 11·9 | Coke moderately swollen, bright, with some cauliflower-like excrescences, firm. Ash, light gray, granular. |
| Sample from the Vale of Clwydd Colliery, near Lithgow. Taken from the rise workings ... ... ... ... ... | ·90 | 34·75 | 51·15 | 13·20 | ·576 | 1·357 | 64·35 | 11·8 | Coke, slightly swollen, firm and lustrous, some cauliflower-like excrescences. Ash, very light gray, granular. |
| Sample from the Zig Zag Colliery, near Lithgow. Taken from the Main-dip workings ... ... ... ... ... | ·95 | 34·35 | 52·55 | 12·15 | ·576 | 1·360 | 64·70 | 12·1 | Coke, fairly swollen, firm and lustrous, numerous cauliflower-like excrescences. Ash, white, granular. |

The average composition of the coal from the collieries of the Western Coalfield, as calculated from the above thirteen analyses, is as follows:—

| | |
|---|---|
| Hygroscopic moisture ... ... ... ... ... ... | 1·87 |
| Volatile hydrocarbons ... ... ... ... ... ... | 31·49 |
| Fixed Carbon ... ... ... ... ... ... ... | 52·61 |
| Ash ... ... ... ... ... ... ... ... .. | 14·03 |
| | 100·00 |

Sulphur, ·626 per cent.

*Production of Coal.*

Quantity and Value of Coal raised from the opening of the Coal-seams to 1857 inclusive.

| Year. | Quantity. | Average per ton. | Value. | Year. | Quantity. | Average per ton. | Value. |
|---|---|---|---|---|---|---|---|
| Prior to— | | £ s. d. | £ | Prior to— | | £ s. d. | £ |
| 1829 .. ... ... | 50,000 | 0 10 0·00 | 25,000 | 1844 ... ... | 23,118 | 0 10 8·34 | 12,363 |
| 1829... ... ... | 780 | 0 10 1·23 | 394 | 1845 ... ... | 22,324 | 0 7 10·27 | 8,769 |
| 1830... ... ... | 4,000 | 0 9 0·00 | 1,800 | 1846 ... ... | 38,965 | 0 7 0·46 | 13,714 |
| 1831... ... ... | 5,000 | 0 8 0·00 | 2,000 | 1847 ... ... | 40,732 | 0 6 9·01 | 13,750 |
| 1832... ... ... | 7,143 | 0 7 0·00 | 2,500 | 1848 ... ... | 45,447 | 0 6 3·38 | 14,275 |
| 1833... ... ... | 6,812 | 0 7 6·73 | 2,575 | 1849 ... ... | 48,516 | 0 6 0·45 | 14,647 |
| 1834... ... ... | 8,490 | 0 8 10·00 | 3,750 | 1850 ... ... | 71,216 | 0 6 6·77 | 23,375 |
| 1835... ... ... | 12,392 | 0 8 10·19 | 5,483 | 1851 ... ... | 67,610 | 0 7 6·51 | 25,546 |
| 1836... ... ... | 12,646 | 0 9 1·06 | 5,747 | 1852 ... ... | 67,404 | 0 10 11·33 | 36,885 |
| 1837... ... ... | 16,083 | 0 9 8·81 | 7,828 | 1853 ... ... | 96,809 | 0 16 1·51 | 78,059 |
| 1838... ... ... | 17,220 | 0 9 9·05 | 8,399 | 1854 ... ... | 116,642 | 1 0 5·63 | 119,380 |
| 1839... ... ... | 21,283 | 0 9 9·73 | 10,441 | 1855 ... ... | 137,076 | 0 12 11·96 | 89,082 |
| 1840... ... ... | 30,256 | 0 10 10·86 | 16,498 | 1856 ... ... | 189,960 | 0 12 4·06 | 117,906 |
| 1841... ... ... | 34,841 | 0 12 0·00 | 20,905 | 1857 ... ... | 210,434 | 0 14 0·97 | 148,158 |
| 1842... ... ... | 39,900 | 0 12 0·00 | 23,940 | | 1,468,961 | 0 11 10·72 | 869,391 |
| 1843... ... ... | 25,862 | 0 12 6·54 | 16,222 | | | | |

TABLE showing the Quantities and Average Value per ton of Coal exported to Intercolonial and Foreign Ports respectively, the Quantity of Coal consumed in this Colony, and the Average Price per ton of the total output of the Collieries, from the opening of the Coal-seams to 1899 inclusive.

| Year. | Exports to Intercolonial Ports. | | | Exports to Foreign Ports. | | | Total Exports. | | | Home consumption. | Total Output and Value. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity. | Average per ton. | Value. | Quantity. | Average per ton. | Value. | Quantity. | Average per ton. | Value. | | Quantity. | Average per ton. | Value. |
| | tons. | £ s. d. | £ | tons. | £ s. d. | £ | tons. | £ s. d. | £ | tons. | tons. | £ s. d. | £ s. d. |
| To end of 1857* | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 1,468,961† | 1,468,961 | 0 11 10·72 | 869,391 0 0 |
| 1858 | 101,488 | 0 15 1·67 | 76,824 | 12,039 | 1 0 1·85 | 12,132 | 113,527 | 0 15 8·05 | 88,956 | 102,870 | 216,397 | 0 14 11·84 | 162,162 0 0 |
| 1859 | 129,586 | 0 14 6·67 | 94,312 | 44,349 | 0 17 5·27 | 38,672 | 173,935 | 0 15 3·49 | 132,984 | 134,278 | 308,213 | 0 13 3·14 | 204,371 0 0 |
| 1860 | 140,183 | 0 14 10·85 | 104,471 | 93,694 | 0 16 11·10 | 79,290 | 233,877 | 0 15 8·57 | 183,761 | 134,985 | 368,862 | 0 12 3·36 | 226,493 0 0 |
| 1861 | 157,278 | 0 15 2·26 | 119,433 | 50,502 | 0 16 6·37 | 41,532 | 207,780 | 0 15 5·92 | 160,965 | 134,287 | 342,067 | 0 12 9·52 | 218,820 0 0 |
| 1862 | 195,427 | 0 15 0·55 | 147,019 | 113,355 | 0 17 4·34 | 98,403 | 308,782 | 0 15 10·75 | 245,422 | 167,740 | 476,522 | 0 12 9·73 | 305,234 0 0 |
| 1863 | 213,909 | 0 13 8·40 | 146,532 | 84,129 | 0 17 6·10 | 73,649 | 298,038 | 0 14 9·30 | 220,181 | 135,851 | 433,889 | 0 10 10·66 | 236,230 0 0 |
| 1864 | 283,539 | 0 10 3·74 | 146,199 | 88,927 | 0 14 10·90 | 66,289 | 372,466 | 0 11 4·91 | 212,488 | 176,546 | 549,012 | 0 9 10·10 | 270,171 0 0 |
| 1865 | 292,664 | 0 9 11·83 | 146,129 | 90,304 | 0 15 0·79 | 68,029 | 382,968 | 0 11 2·20 | 214,158 | 202,657 | 585,525 | 0 9 4·43 | 274,303 0 0 |
| 1866 | 344,194 | 0 9 2·98 | 159,175 | 196,711 | 0 14 4·53 | 141,413 | 540,905 | 0 11 1·37 | 300,588 | 233,333 | 774,238 | 0 8 4·44 | 324,049 0 0 |
| 1867 | 312,101 | 0 9 4·35 | 146,111 | 161,256 | 0 13 3·47 | 107,148 | 473,357 | 0 10 8·40 | 253,259 | 296,655 | 770,012 | 0 8 10·79 | 342,655 0 0 |
| 1868 | 329,052 | 0 9 5·76 | 155,975 | 218,984 | 0 12 5·29 | 136,226 | 548,036 | 0 10 7·96 | 292,201 | 406,195 | 954,231 | 0 8 9·08 | 417,309 0 0 |
| 1869 | 340,466 | 0 8 9·07 | 149,059 | 255,087 | 0 11 8·31 | 149,136 | 595,553 | 0 10 0·16 | 298,195 | 324,221 | 919,774 | 0 7 6·32 | 346,146 0 0 |
| 1870 | 335,564 | 0 8 0·02 | 142,656 | 242,825 | 0 10 3·57 | 125,025 | 578,389 | 0 9 3·07 | 267,681 | 290,175 | 868,564 | 0 7 3·54 | 316,836 0 0 |
| 1871 | 378,891 | 0 8 6·91 | 162,470 | 186,538 | 0 10 1·22 | 94,220 | 565,429 | 0 9 0·95 | 256,690 | 333,355 | 898,784 | 0 7 0·47 | 316,340 0 0 |
| 1872 | 394,052 | 0 8 8·11 | 170,947 | 275,058 | 0 0 11·46 | 136,914 | 669,110 | 0 9 2·42 | 307,861 | 343,316 | 1,012,426 | 0 7 9·92 | 396,198 0 0 |
| 1873 | 425,937 | 0 12 9·32 | 272,110 | 347,142 | 0 14 7·59 | 253,979 | 773,079 | 0 13 7·32 | 526,089 | 419,783 | 1,192,862 | 0 11 1·94 | 665,747 0 0 |
| 1874 | 467,583 | 0 13 8·30 | 320,119 | 405,442 | 0 15 4·76 | 312,128 | 873,025 | 0 14 5·81 | 632,247 | 431,587 | 1,304,612 | 0 12 1·37 | 790,224 0 0 |
| 1875 | 518,853 | 0 13 7·77 | 354,074 | 408,154 | 0 15 6·64 | 317,409 | 927,007 | 0 14 5·84 | 671,483 | 402,722 | 1,329,729 | 0 12 3·89 | 819,429 17 2 |
| 1876 | 542,952 | 0 13 8·45 | 372,046 | 325,865 | 0 15 6·45 | 253,160 | 868,817 | 0 14 4·70 | 625,211 | 451,101 | 1,319,918 | 0 12 2·06 | 803,300 5 6 |

* For details see preceding table

† This item includes also all exports prior to 1858.

| Year. | Exports to Intercolonial Ports. Quantity. | Average per ton. | Value. | Exports to Foreign Ports. Quantity. | Average per ton. | Value. | Total Exports. Quantity. | Average per ton. | Value. | Home consumption. | Total Output and Value. Quantity. | Average per ton. | Value. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| To end of | tons. | £ s. d. | £ | tons | £ s. d. | £ | tons. | £ s. d. | £ | tons. | tons. | £ s. d. | £ s. d. |
| 1877 | 563,757 | 0 13 8·64 | 386,740 | 351,970 | 0 14 10·81 | 262,237 | 915,727 | 0 14 2·08 | 648,977 | 628,544 | 1,444,271 | 0 11 10·74 | 858,998 8 2 |
| 1878 | 623,323 | 0 13 8·77 | 427,954 | 383,097 | 0 14 7·69 | 280,452 | 1,006,420 | 0 14 0·93 | 708,406 | 569,077 | 1,575,497 | 0 11 8·28 | 920,936 7 4 |
| 1879 | 621,087 | 0 13 6·75 | 421,198 | 376,962 | 0 14 6·13 | 273,509 | 998,049 | 0 13 11·05 | 694,707 | 585,332 | 1,583,381 | 0 12 0·12 | 950,878 18 3 |
| 1880 | 550,672 | 0 11 2·67 | 309,004 | 202,684 | 0 11 5·70 | 116,295 | 753,356 | 0 11 3·48 | 425,299 | 712,824 | 1,466,180 | 0 8 6·36 | 615,336 11 7 |
| 1881 | 657,135 | 0 7 9·34 | 255,572 | 372,709 | 0 8 8·29 | 161,958 | 1,029,844 | 0 8 1·30 | 417,530 | 739,753 | 1,769,597 | 0 6 9·55 | 603,248 5 8 |
| 1882 | 760,226 | 0 9 9·54 | 372,334 | 501,319 | 0 10 11·50 | 274,699 | 1,261,545 | 0 10 3·09 | 647,033 | 847,737 | 2,109,282 | 0 8 11·97 | 943,965 0 0 |
| 1883 | 855,704 | 0 10 5·75 | 448,356 | 656,741 | 0 11 7·34 | 381,306 | 1,512,445 | 0 10 11·66 | 829,662 | 1,009,012 | 2,521,457 | 0 9 6·40 | 1,201,941 12 11 |
| 1884 | 994,087 | 0 10 8·66 | 532,938 | 696,676 | 0 11 5·14 | 398,107 | 1,690,763 | 0 11 0·15 | 931,045 | 1,058,346 | 2,749,109 | 0 9 5·71 | 1,303,076 19 11 |
| 1885 | 991,924 | 0 10 7·13 | 525,443 | 764,432 | 0 11 6·52 | 441,220 | 1,756,356 | 0 11 0·09 | 966,663 | 1,122,507 | 2,878,863 | 0 9 3·72 | 1,340,212 13 7 |
| 1886 | 1,027,775 | 0 10 7·22 | 544,824 | 708,090 | 0 11 4·31 | 402,178 | 1,735,865 | 0 10 10·93 | 947,002 | 1,094,310 | 2,830,175 | 0 9 2·53 | 1,303,164 4 1 |
| 1887 | 1,077,270 | 0 10 5·89 | 565,084 | 713,172 | 0 11 1·08 | 395,455 | 1,790,442 | 0 10 8·75 | 960,539 | 1,132,055 | 2,922,497 | 0 9 2·57 | 1,346,440 2 7 |
| 1888 | 1,039,764 | 0 10 10·25 | 664,293 | 884,108 | 0 11 3·77 | 500,179 | 1,923,872 | 0 11 0·78 | 1,064,472 | 1,279,572 | 3,203,444 | 0 9 1·02 | 1,455,198 4 1 |
| 1889 | 1,310,228 | 0 10 4·24 | 678,200 | 1,077,474 | 0 11 1·88 | 601,071 | 2,387,702 | 0 10 8·58 | 1,279,271 | 1,267,930 | 3,655,632 | 0 8 11·20 | 1,632,848 15 6 |
| 1890 | 1,149,544 | 0 10 6·96 | 608,108 | 672,330 | 0 11 3·31 | 379,065 | 1,821,874 | 0 10 10·04 | 987,173 | 1,239,002 | 3,060,876 | 0 8 4·29 | 1,279,088 19 5 |
| 1891 | 1,397,256 | 0 10 0·30 | 700,380 | 847,473 | 0 10 10·43 | 460,595 | 2,244,729 | 0 10 4·12 | 1,160,965 | 1,793,200 | 4,037,929 | 0 8 7·58 | 1,742,795 12 6 |
| 1892 | 1,318,008 | 0 8 10·89 | 587,016 | 873,697 | 0 10 1·24 | 441,379 | 2,191,705 | 0 9 4·61 | 1,028,395 | 1,589,263 | 3,780,968 | 0 7 8·82 | 1,462,388 9 4 |
| 1893 | 1,160,238 | 0 8 6·05 | 493,372 | 674,852 | 0 9 6·35 | 321,557 | 1,835,090 | 0 8 10·57 | 814,929 | 1,443,238 | 3,278,328 | 0 7 1·78 | 1,171,722 4 6 |
| 1894 | 1,175,072 | 0 7 1·73 | 419,751 | 950,053 | 0 8 1·26 | 385,018 | 2,125,125 | 0 7 6·88 | 804,769 | 1,546,951 | 3,672,076 | 0 6 3·53 | 1,155,573 7 10 |
| 1895 | 1,196,504 | 0 6 9·69 | 407,271 | 969,726 | 0 7 6·75 | 366,683 | 2,166,230 | 0 7 1·74 | 773,954 | 1,572,359 | 3,738,589 | 0 5 10·31 | 1,095,327 1 0 |
| 1896 | 1,371,796 | 0 7 0·34 | 482,096 | 1,103,111 | 0 7 6·98 | 418,168 | 2,474,907 | 0 7 3·30 | 900,264 | 1,434,610 | 3,909,517 | 0 5 9·08 | 1,125,280 16 7 |
| 1897 | 1,498,992 | 0 6 11·49 | 521,462 | 1,197,631 | 0 7 2·20 | 430,592 | 2,696,623 | 0 7 0·73 | 952,054 | 1,686,968 | 4,383,591 | 0 5 7·34 | 1,230,041 1 1 |
| 1898 | 1,629,072 | 0 6 9·19 | 551,083 | 1,162,724 | 0 7 0·06 | 411,585 | 2,791,796 | 0 0 10·76 | 962,668 | 1,914,455 | 4,706,251 | 0 5 4·86 | 1,271,832 0 0 |
| 1899 | 1,624,137 | 0 6 9·81 | 553,629 | 1,174,386 | 0 7 8·40 | 452,105 | 2,798,523 | 0 7 2·26 | 1,005,794 | 1,798,505 | 4,597,028 | 0 5 9·22 | 1,325,798 12 5 |
| | 30,497,290 | 0 9 8·01 | 14,741,768 | 20,915,778 | 0 10 6·91 | 11,060,233 | 51,413,068 | 0 10 0·45 | 25,802,001 | 34,556,068 | 85,969,136 | 0 8 3·51 | 35,647,004 2 0 |

# COKE.

An examination was made by the Author, in the year 1892,* of the coke manufactured in the Colony, and also of the various coal-washing plants connected with coke works. At that date coke ovens were at work at eight localities, but a preliminary washing of the coal, for the purpose of separating the shale or dirt, was only practised at four of them. The investigation referred to was made with the object of comparing (1) the crushing strength, and (2) the percentage of ash of the colonial coke with those of the foreign coke imported by the Broken Hill Silver-mining Companies, as it had been asserted that the colonial-made article was inferior in both respects, and could not therefore be economically used for smelting purposes at Broken Hill.

Samples of the coke imported from Germany, Wales, and New Zealand, were accordingly taken from the heaps at Broken Hill and Port Pirie, as were also samples from the various coke works in New South Wales, and these were all analysed by Mr. J. C. H. Mingaye, in the Laboratory of the Department of Mines. Cubes were then carefully cut (on an emery wheel) from the various samples of coke, and these were subject to a crushing test in the testing machine at the Sydney University. The results of the analyses and crushing tests of the various cokes were found to be as follows:—

| No. | Description of Coke. | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Crushing Strength, in lb. per square inch. |
|---|---|---|---|---|---|---|---|---|
| | A. Foreign Cokes. | | | | | | | |
| 1. | Hood's (Welsh) Coke, sample taken from Broken Hill Proprietary Smelting Works. | ·70 | 1·00 | 92·71 | 4·75 | ·84 | 1·864 | ... |
| 2. | Hood's (Welsh) Coke, No. 1 sample, taken from Port Pirie. | ·20 | ·30 | 92·71 | 5·85 | ·94 | 1·928 | ... |
| 3. | Hood's (Welsh) Coke, No. 2 sample, taken from Port Pirie. | 1·30 | 1·00 | 88·19 | 8·20 | 1·31 | 1·834 | 765 |
| 4. | Hood's (Welsh) Coke, sample taken from the Central Broken Hill Smelting Works. | ·36 | ·37 | 88·86 | 9·70 | ·71 | 2·030 | ... |
| 5. | Brancepeth (Welsh) Coke, sample taken at Port Pirie. | ·80 | ·85 | 91·93 | 5·50 | ·92 | 1·843 | 551 |
| 6. | Brancepeth (Welsh) Coke, sample taken from Broken Hill Proprietary Smelting Works. | ·62 | 1·63 | 89·20 | 7·80 | ·75 | 1·942 | ... |
| 7. | Westport (New Zealand) Coke, sample taken at Port Pirie. | ·85 | 1·05 | 89·53 | 7·15 | 1·42 | 1·827 | 747 |
| 8. | "Shamrock" (Westphalian) Coke, sample taken at Port Pirie. | ·35 | ·15 | 89·69 | 7·30 | 2·51 | 1·820 | 478 |
| 9. | Hamburg (German) Coke, sample taken at Port Pirie. | ·35 | ·55 | 88·58 | 9·20 | 1·32 | 1·851 | ... |

* Ann. Rept. Dept. Mines, N.S. Wales, for 1892, pp. 35-37.

| No. | Description of Coke | Hygroscopic Moisture. | Volatile Hydrocarbons. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Crushing Strength, in lb. per square inch. |
|---|---|---|---|---|---|---|---|---|
| | B. Colonial Cokes. | | | | | | | |
| 1. | Purified Coal and Coke Company's Coke, Wallsend, sample No. 1, from washed coal. | ·40 | ·02 | 91·33 | 7·82 | ·43 | 1·964 | 1,368 |
| 2. | Purified Coal and Coke Company's Coke, Wallsend, sample No. 2, from washed coal. | ·41 | ·51 | 90·54 | 8·01 | ·53 | 1·837 | 1,899 |
| 3. | Purified Coal and Coke Company's Coke, Wallsend, sample No. 3, from washed coal. | ·42 | ·00 | 90·79 | 8·38 | ·41 | 1·850 | 2,383 |
| 4. | Singleton Colliery Coke, Rix's Creek, made from washed coal. | ·67 | ·11 | 89·02 | 9·67 | ·53 | 1·798 | 2,011 |
| 5. | Vale Colliery (Lithgow) Coke, made from washed coal. | 1·08 | ·12 | 82·74 | 15·47 | ·59 | 1·829 | ... |
| 6. | Bulli Colliery Coke, made from washed coal. | 1·15 | ·90 | 83·98 | 13·40 | ·57 | 1·629 | 3,125 |
| 7. | Co-operative Colliery Coke, Wallsend, sample No. 1, made from unwashed coal. | 1·37 | ·27 | 87·77 | 10·45 | ·64 | 1·844 | 619 |
| 8. | Co-operative Colliery Coke, Wallsend, sample No. 2, made from unwashed coal. | ·22 | ·34 | 86·71 | 12·06 | ·67 | 1·813 | 1,343 |
| 9. | Unanderra (Wollongong) Coke, made from unwashed coal. | ·29 | ·15 | 87·55 | 11·56 | ·45 | 1·934 | ... |
| 10. | Brown's Minmi Colliery Coke, made from unwashed coal. | ·62 | ·32 | 85·65 | 12·62 | ·79 | 1·737 | ... |
| 11. | Mount Pleasant (Wollongong) Coke, made from unwashed coal. Mean of four analyses. | ·85 | ·23 | 83·90 | 14·59 | ·43 | 1·829 | ... |

The conclusions arrived at were summarised in the report, as follows :—

(1.) That there was room for material improvement in the manufacture of colonial coke, both in the direction of reducing the ash, and increasing the density, or capacity for resisting pressure, and that these improvements could best be achieved by a more perfect system of coal-washing, and by the use of a more modern type of coke oven.

(2.) That some of the cokes manufactured in New South Wales were nearly equal, as regards ash, to the *average* of the imported cokes in use at the Broken Hill Smelting Works.

(3.) That several of the cokes manufactured in New South Wales were superior, as regards percentage of ash, to some of the imported cokes in use at Broken Hill.

(4.) That, in regard to strength or capacity for resisting pressure, most of the cokes manufactured in New South Wales were vastly superior to the imported cokes used at Broken Hill.

It cannot be said that the manufacture of colonial coke has undergone any very marked improvement since the publication, in 1892, of the report referred to; the ordinary Beehive oven is still used in a majority of instances, and the preliminary washing of the coal, so far from becoming more general, has been actually stopped in one case (viz., at the Bulli Coke Works), while in another, at Rix's Creek, only a small proportion of the coke is now made from washed coal.

*Photographed by E. F. Pittman.*

THE PURIFIED COAL AND COKE COMPANY'S WORKS, WALLSEND, NEAR NEWCASTLE.

There are, at the present time, ten coke works in the Colony, and at only four of these is the coal subjected to a washing process before being charged into the coke ovens. In the Northern Coal-field, there are four coke works, viz. :—(1) The Purified Coal and Coke Company, near Wallsend; (2) The Singleton Coal and Coke Company, at Rix's Creek; (3) The Co-operative Coal and Coke Company, at Wallsend; (4) Brown's Minmi Colliery Coke Works, at Minmi. At the first-named works, the coal is washed before being converted into coke, while at the second, a portion only of the coal produced, viz., the "smalls," is washed. In the Southern Coal-field, there are five coke-making establishments, viz. :—(1) The Mount Lyell Mining and Railway Company's Coke Works, at Port Kembla; The Great Australian Coke-making Company, Unanderra; (3) The Bulli Colliery Coke Works, at Bulli; (4) The Mount Pleasant Colliery Coke Works, near Wollongong; and (5) The South Clifton Colliery Coke Works, South Clifton. At only one of these, viz., the Mount Lyell Works, Port Kembla, is a preliminary washing given to the coal. In the Western Coal-field, the only coke works are those of the Oakey Park Coal-mining Company near Lithgow, and here also the coal is washed before being converted into coke.

*The Purified Coal and Coke Company's Works* are situated near Wallsend. At these works, a mixture of two qualities of small coal from the Wallsend Company's Colliery, with a certain proportion of "smalls" from the Bulli Seam (Illawarra) is used. The Wallsend coal from near the outcrop of the seam is fairly low in ash, but makes a rather weak coke; it is accordingly mixed with an equal quantity from the deeper workings, as this coal makes a stronger coke, while containing rather more dirt. To this mixture is then added from one-eighth to one-sixth its volume of Southern small coal, which, although raising the percentage of ash, has the effect of materially increasing the strength of the resulting coke. The mixed smalls are delivered into a hopper whence they are carried by an elevator to a pair of rolls. After being thus crushed, the material is carried by another elevator to distributing troughs, which divide it amongst three pulsating washing machines or bashes. The shale and "brass," associated with the coal, fall through gratings in these machines, and are carried away by a sluice, while the cleaned coal is thrown forward by the water on to screens, which separate it into blacksmith's nuts and fine coal. The latter is carried downwards by a traveller, furnished with a perforated bottom, and thus reaches the next pair of rolls in a sufficiently dry condition. After being crushed fine between these rolls it is elevated to trucks, whence it is charged into the coke ovens. The plant includes seventy beehive ovens, and the output is about 1,700 tons of coke per month. The charge is burned for about 84 hours.

At the *Singleton Coal and Coke Company's Works*, Rix's Creek, there are forty ovens, thirty-six of which are of the Beehive type, while four are those known as "arched" or "culvert" ovens. The charge is burned for from 72 to 76 hours, and the output is about 1,100 tons of coke per month. The coke nearly all goes to the Cobar and Nymagee Copper-smelting Works, and to the Lithgow Copper Refinery Works. Three classes of coke are made at the Rix's Creek Works:—(1.) In the first the coal, as it comes from the colliery (whole coal and smalls), is charged direct from the mine trucks into the ovens. (2.) In another series of ovens coke is made direct from the large coal, after separation from the "smalls" upon a $\frac{3}{4}$-inch screen, but without crushing. (3.) In a third series of ovens coke is made from the "smalls" which pass through the screen just mentioned. These smalls are thrown into wooden sluice boxes, where they are washed by a stream of water, which effects a somewhat imperfect separation of the coal from the shale and "brass." The washed material is then put over a half-inch screen, which separates it into blacksmith's nuts and "duff"; the nuts are sold locally, while the duff is charged into the coke ovens. There is only sufficient water available at the works to wash about ten tons of the small coal per day, so that the bulk of the coke produced by this company is made from unwashed coal.

*The Co-operative Coal and Coke Company*, whose works are situated at Wallsend, have one rectangular oven and sixty-six Beehives. Their output is about 320 tons per week, and the coke is disposed of chiefly to the Cockle Creek Smelting Works, and to Cobar. The coal used is unwashed slack from the Co-operative Colliery. The charges are kept in the ovens for about 96 hours.

*The Minmi Colliery Coke Works* have been idle for several years, but they have a considerable quantity of coke on hand in stacks. The plant includes thirty-two Beehive ovens, but no coal-washing machinery.

*The Mount Lyell Mining and Railway Company's Coke Works, Port Kembla.*—At these works, coal from the Mount Kembla Coal and Oil Company's Mine is used, after being washed in a plant belonging to the latter company, and situated alongside the coke works at Port Kembla. The small coal from the Mount Kembla Colliery is brought to the works by tramway and delivered into bins fitted with trap-doors at the bottom, through which it falls on to a travelling belt and is conveyed to a reservoir, whence it is raised by an elevator to a shoot, which delivers it to a Robinson coal-washing machine. This consists of a hollow inverted cone, into the bottom or smaller end of which a stream of sea-water is delivered by a pulsometer pump. The coal is fed by the shoot into the upper end of the cone, and, as it meets the ascending stream of water, the charge is agitated by revolving stirrers. The shale or dirt sinks to the bottom of the vessel, and is let out by a double valve, actuated by levers. The overflow from the lip of the vessel passes down a shoot into the boot of an elevator furnished with perforated buckets, by which the clean coal is drained and conveyed to storage bins. The total loss in weight by washing is about fifteen per cent.

*Photographed by E. F. Pittman.*

THE MOUNT LYELL MINING AND RAILWAY COMPANY'S COKE WORKS, AND THE MOUNT KEMBLA COLLIERY JETTY AND COAL WASHING PLANT, PORT KEMBLA, NEAR WOLLONGONG.

The very finest coal powder, or "dent," which has a tendency to float, overflows from the boot of the elevator and is conveyed through sloping launders into brick pits, where the bulk of the water is drained off. The launders are fitted with riffles to catch the fine white spar, or calcite, which accompanies the "dent." The coarser-washed coal is then ground fine in a disintegrator, consisting of revolving discs, furnished with cross bars, driven at the rate of about 500 revolutions per minute. It is then mixed with the "dent," and conveyed in trucks to the tops of the ovens.

The plant consists of fifty rectangular ovens, which are a modification of the Coppee type; their dimensions are twenty-four feet in length, by a mean width of three feet four and a half inches. The coke is discharged by a hydraulic ram, travelling on a tramway alongside the ovens, and is quenched outside. Each oven receives a charge of four tons of washed coal, which is burned for forty-eight hours, and the product is from sixty-six to seventy per cent. of the coal charge. The output is about four hundred tons of coke per week, which is all sent to the smelting works of the Mount Lyell Copper-mine, Tasmania. The coke is extremely dense, and capable of bearing a very heavy ore burden in a smelting furnace.

With the object of ascertaining what amount of improvement was effected in the coal by the washing operation, samples were taken of (1) the small coal as delivered from the mine, (2) the coal after washing, and (3) the very fine washed material, or "dent," and these were carefully analysed in the Laboratory of the Department of Mines, with the following results:—

| Description of Sample. | Hygroscopic Moisture. | Volatile hydrocarbons. | Fixed carbon. | Ash. | Sulphur. | Specific gravity. | Calorimetric value. |
|---|---|---|---|---|---|---|---|
| Unwashed coal from the Mount Kembla coal-washing plant. | 1·20 | 23·50 | 61·95 | 13·35 | ·357 | 1·397 | 11·7 |
| Washed coal from the Mount Kembla coal-washing plant. | 1·15 | 23·85 | 62·33 | 12·67 | ·343 | 1·365 | 11·8 |
| Washed "dent," or very fine coal, from the Mount Kembla coal-washing plant. | 2·35 | 24·97 | 61·31 | 11·37 | ·412 | 1·349 | 12·5 |

*The Great Australian Coke-making Company, Unanderra.*—Small coal, which has passed through a 1-inch screen, is purchased by this Company from the Corrimal Colliery. It is delivered into a bin at the coke works, and is elevated on to a shaking screen of $\frac{3}{4}$-inch mesh, which separates it into "nuts" and "fines"; the former are again elevated to a hopper and sold for private consumption. The "fines" pass through a disintegrator, and the finely pulverised material, or "duff" is then elevated into the duff hopper, whence it is loaded into trucks which run along the tops of the ovens. A second quality of coke is made by sending the colliery "smalls" direct to the disintegrator, instead of first treating them on the shaking screen. There is no coal-washing plant at these works, which, however, have the largest output in the Colony. The coke goes chiefly to Broken Hill and Port Pirie. The works contain ninety-four ovens, seventy of which are Beehives, while twenty-four are arched or "culvert" ovens. The coke is quenched inside the ovens and drawn by manual labour. On Mondays, Tuesdays, Wednesdays, and Thursdays, the charges consist of 3½ tons of coal per oven, while Friday's and Saturday's charges are 6 tons; the small charges are burned for forty-eight hours, while the large ones are kept in the ovens for three days.

*The Bulli Colliery Coke Works.*—A few years ago these works were provided with a Sheppard coal-washing plant, but this has been removed and the coke is now made from unwashed coal. The "smalls" from the Bulli Mine, after passing through a 1-inch screen, are delivered into a bin, from which they empty into a shaking-screen with a false bottom of wire netting of ½-inch mesh. The "nuts" which pass over this screen are elevated into a hopper and sold for private consumption. The "fines" are crushed still further in a disintegrator, and are then elevated into a hopper from which they pass into trucks, and are delivered at the tops of the ovens ready for charging. The plant includes forty rectangular ovens, which are a modification of the Coppee type. The charges are from three to four tons of coal and the period of burning is forty-eight hours, except for Friday's charge which is burned for three days. Hitherto the greater portion of the product has been used at the Mount Lyell Mine, Tasmania, but the contract has now expired and will probably not be renewed, as that mine now possesses its own coke works. Some of the Bulli coke goes to Cockle Creek works, some to San Francisco, and there is also a Sydney and a local trade.

*The Mount Pleasant Coke Works, near Wollongong.*—There are fourteen Beehive ovens at these works where unwashed coal only is used. The charge varies according to the day of the week, Friday's and Saturday's charges being larger so as to avoid work on Sunday, and the time of burning for the smaller charge is forty-eight hours, while for the larger it is three days. The maximum output, when all the ovens are in full work is 120 tons per week; but it is not always possible to obtain sufficient small coal, and the average output is about 100 tons per week. The coke goes to the Dapto Smelting Works and to small foundries in Sydney. The supply of small coal is purchased from the Mount Pleasant Colliery, and is delivered from the trucks into a bin at the works; it is then pulverised in a disintegrator whence it is elevated to trucks which run over the tops of the ovens.

*The South Clifton Coal-mining Company's Coke Works.*—These are situated at the South Clifton Colliery and consist of sixteen Beehive ovens of eleven feet diameter. There is no coal-washing plant at these works. The coal as it comes from the mine is treated on three shaking screens of 3-inch, $1\frac{3}{8}$-inch, and $\frac{3}{8}$-inch mesh respectively; by these means it is separated into whole coal, large nuts, small nuts, and duff. The duff is carried about thirty yards by a conveyer and is then elevated to a bin, from the bottom of which it is carried by a second conveyer and charged into the ovens, so that up to this stage the work is all performed automatically. The charges are four and a half tons per oven for the first three days of the week, and five and a quarter tons on Thursday, Friday, and Saturday; the smaller charges are burned for three days and the larger for four. The coke goes to Broken Hill and Mount Lyell. This company is the only one in the Colony which utilises the gases from the coke ovens; a large brick flue conveys the heated gases from the tops of the ovens to the Lancashire boilers connected with the winding plant, where they are utilised for steam-raising. A considerable saving is thus effected, for the coal which is usually employed for this purpose is worth about 5s. per ton to the company.

Messrs. Gill and Johnson own a small coke-making plant close by, and use the duff from the South Clifton Colliery. The plant consists of eight ovens of similar construction to the above. The output is about fifty-five tons per week, and the coke goes chiefly to Mount Lyell though there is also a Sydney and a local trade.

*The Oakey Park Coal-mining Company's Coke Works, near Lithgow.*—There are sixteen Beehive ovens at these works, and it is intended to shortly erect sixteen more. The output at present is forty-five tons of coke per week. It has been found by experience with this coal that it is preferable to use large charges and burn them for a correspondingly long period. One reason for this is that it is customary to discard the "black ends," which are rather friable, and it is found that a large charge only produces about the same quantity of "black ends" as a small one. Accordingly, the usual charge is about five and a half tons of washed small coal, and this is burned for a period of between five and six days. The entire output is sold to the Blayney Copper-smelting Works.

The coal, as it comes from the pit, is tipped on to a 1-inch screen, covering a hopper, and the "smalls" which pass through the screen are loaded from the hopper into trucks of seven hundred-weight capacity. The trucks are then drawn up an inclined tramway by means of an endless chain, and on reaching the top they automatically discharge their contents into a bin with a sloping bottom. The trucks, after emptying themselves, are carried down over the top of the bin to the shaft. From the bin the coal is fed into a disintegrator (Hardy's patent), and as it is discharged from this it meets a stream of water which washes it into sluice-boxes.

There are two of these sluice-boxes, each about twenty-two yards long by fifteen inches wide, and they are worked alternately, the stream being diverted into the second sluice (by means of a movable tongue) when the first has been filled with dirt. The dirt is removed from the sluices by shovels. The water is obtained from the mine workings, being pumped up to elevated storage tanks. The sluice discharges the washed coal into hoppers, from which it is loaded into trucks which run over the tops of the ovens.

### Analyses of New South Wales Cokes.

The following analyses of samples of coke, recently taken from the various coke works of the Colony, have been made in the laboratory of the Department of Mines:—

| Description of Sample. | Hygroscopic Moisture | Volatile Matter. | Fixed Carbon. | Ash. | Sulphur. | Specific Gravity. | Remarks. |
|---|---|---|---|---|---|---|---|
| Northern Coal-field. | | | | | | | |
| The Purified Coal and Coke Company's Works, Wallsend.—Coke made from washed Wallsend coal.. | ·75 | ·40 | 86·20 | 12·21 | ·44 | 1·827 | Ash, reddish brown, granular. |
| The Purified Coal and Coke Company's Works, Wallsend.—Coke made from mixed washed coal from Wallsend and Illawarra .. .. | ·35 | ·35 | 86·78 | 12·08 | ·44 | 1·783 | Ash, reddish brown, granular. |
| Singleton Coal and Coke Company.—Coke made from large and small coal, unwashed .. .. .. | 1·05 | ·50 | 87·83 | 10·14 | ·48 | 1·755 | Ash, reddish tinge, granular. |
| Singleton Coal and Coke Company.—Coke made from large coal, unwashed .. .. .. .. .. | ·35 | ·05 | 90·30 | 8·86 | ·44 | 1·831 | Ash, reddish brown, granular. |
| Singleton Coal and Coke Company.—Coke made from washed small coal | ·15 | ·45 | 88·85 | 10·11 | ·44 | 1·783 | Ash, yellowish, granular. |
| The Co-operative Coal and Coke Company, Wallsend.—Coke made from unwashed coal .. .. .. | 2·65 | ·60 | 86·50 | 9·79 | ·46 | 1·783 | Ash, yellowish, granular. |
| The Minmi Colliery (Brown's).—Coke made from unwashed coal .. | 2·85 | 1·05 | 83·88 | 11·84 | ·38 | 1·815 | Ash, yellowish, granular. |
| Southern Coal-field. | | | | | | | |
| The Mount Lyell Mining and Railway Company's Coke Works, Port Kembla.—Coke made from washed coal | 1·17 | 1·53 | 82·48 | 15·98 | ·47 | 2·278 | Ash, light brown, granular. |
| The Mount Lyell Mining and Railway Company's Coke Works, Port Kembla.—Coke made from washed coal and duff .. .. .. .. | ·85 | 1·87 | 82·48 | 14·30 | ·50 | 2·134 | Ash, brownish tinge, granular. |
| The Great Australian Coke-making Company, Unanderra.—Coke made from screened coal, unwashed .. | 1·85 | 1·10 | 83·05 | 13·60 | ·40 | 1·753 | Ash, grayish, granular. |
| The Bulli Colliery Coke Works.—Coke made from unwashed coal .. .. | 1·15 | ·50 | 82·00 | 15·82 | ·53 | 1·843 | Ash, grayish, granular. |
| The Mount Pleasant Coke Works.—Coke made from unwashed coal .. | ·75 | ·52 | 85·21 | 13·08 | ·44 | 1·792 | Ash, reddish tinge, granular. |
| Messrs. Gill and Johnson's Coke Works, South Clifton.—Coke made from unwashed coal.. .. | 1·33 | ·40 | 83·14 | 14·68 | ·45 | 1·819 | Ash, buff-coloured, granular. |
| Western Coal-field. | | | | | | | |
| Oakey Park Colliery's Coke Works, Lithgow.—Coke made from washed coal .. .. .. .. | 4·12 | 2·10 | 78·41 | 14·67 | ·70 | 2·711 | Ash, light gray, granular. |

*Production of Coke.*

Table showing the Quantity and Value of Coke made in the Colony of New South Wales.

| Year. | Quantity. | | | | Total Value. | | |
|---|---|---|---|---|---|---|---|
| | Northern District. | | Southern and Western Districts. | | | | |
| | tons | cwt. | tons | cwt. | £ | s. | d. |
| 1890 ... ... ... ... | 15,886 | 2 | 15,211 | 0 | 41,147 | 3 | 7 |
| 1891 ... ... ... ... | 9,474 | 2 | 20,836 | 5 | 34,473 | 5 | 10 |
| 1892 ... ... ... ... | 5,245 | 0 | 2,654 | 0 | 8,852 | 8 | 6 |
| 1893 ... ... ... ... | 12,262 | 0 | 5,596 | 0 | 20,233 | 2 | 0 |
| 1894 ... ... ... ... | 13,602 | 5 | 20,855 | 19 | 33,209 | 5 | 7 |
| 1895 ... ... ... ... | 11,326 | 8 | 16,304 | 0 | 24,683 | 5 | 0 |
| 1896 ... ... ... ... | 10,398 | 10 | 15,953 | 0 | 21,850 | 16 | 3 |
| 1897 ... ... ... ... | 21,012 | 0 | 43,190 | 0 | 45,391 | 18 | 0 |
| 1898 ... ... .. ... | 34,422 | 0 | 47,800 | 0 | 64,134 | 17 | 0 |
| 1899 ... ... ... ... | 43,912 | 0 | 52,618 | 0 | 77,129 | 10 | 1 |
| Totals ... ... | 177,540 | 7 | 241,018 | 4 | 371,105 | 11 | 10 |

# KEROSENE SHALE.

This name has been applied to a variety of Torbanite, Cannel Coal, or Boghead Mineral which occurs in a number of localities, and on at least three geological horizons, viz., one in the Lower and two in the Upper Coal Measures of the Permo-Carboniferous system. The name Kerosene Shale is an unsatisfactory one, because the mineral has little or none of the character of shale, in that it does not, at any rate in hand specimens, cleave or split readily parallel to the laminæ, which latter, as a rule, are only visible in weathered specimens. It is a brownish black dense substance, devoid of lustre; it has a most characteristic conchoidal fracture Its streak is buff coloured; when of good quality it ignites readily with a match, and continues to burn with a luminous smoky flame after the match has been withdrawn. It can be cut readily with a knife or turned in a lathe, and is tough and elastic; the latter characteristic has frequently been the cause of accidents, as the shale has a tendency, when being wrought in mines, to fly out in large pieces, which are liable to cut or otherwise injure the miners. The weathered surfaces of the mineral are usually of a light gray colour, and there is frequently a thin film of whitish clay in the joints. The following is the composition of a specimen of the purest kerosene shale from Joadja, according to an analysis made in the Laboratory of the Department of Mines:—

| | | |
|---|---|---|
| Hygroscopic moisture ... ... | ·16 | |
| Volatile hydrocarbons ... ... | 89·59 | |
| Fixed carbon ... ... ... | 5·27 | Sulphur = ·384 %. |
| Ash ... ... ... ... | 4·98 | Specific gravity = 1·008. |
| | 100·00 | |

This sample, however, was of exceptional purity, and the mineral is found to vary considerably in quality in different deposits, the percentage of volatile hydrocarbons decreasing, and the proportion of ash increasing materially in the poorer qualities. According to a report by the late Mr. C. S. Wilkinson, Geological Surveyor in Charge, in 1890, the richest kerosene shale at the Joadja Mine, near Mittagong, yielded 15,399 cubic feet of 48-candle gas, or 130 gallons of crude oil per ton, and had a specific gravity of 1·098. Mr. John Mackenzie, late Examiner of Coal-fields, reported in 1875 that the Hartley Vale kerosene shale yielded from 150 to 160 gallons of crude oil, or 18,000 cubic feet of gas (with an illuminating power of 40 candles), per ton; he also stated that the seam at its thickest part measured five feet, the centre three feet being the richest.

*History of the discovery of Kerosene Shale.*—In a book, published in 1827, entitled "Two Years in New South Wales," Vol. II, p. 4, Mr. P. Cunningham refers to a discovery of coal which some authors have supposed to be kerosene shale. The following extract from the work, however, would seem to indicate that the substance referred to by Mr. Cunningham was probably lignite and not kerosene shale:—"A singular species of coal has also been found *at Bathurst*, resembling in some degree the Scotch cannel coal, serving as a sort of connecting link between it and *charcoal, which latter it resembles very closely*, being nearly as light, *and breaking with a similar fracture*, while it burns almost with the steady brightness of a candle. It appears indeed to form the connecting link hitherto wanted, as a demonstration that coal is of vegetable formation, for *if the outer whitish stony crust were broken off, I think the ablest geologists would unhesitatingly declare it to be the absolute charcoal of some particular species of wood.*" Now it cannot be said that kerosene shale very strongly resembles charcoal, or that it breaks with a similar fracture; moreover it is perfectly dense, and there is a complete absence of woody structure in it. Finally it may be said that there is no deposit of kerosene shale, so far as is known at present, within at least forty miles of Bathurst.

Apparently the oldest authentic record of the discovery of kerosene shale is contained in Count Strzelecki's book, entitled "Physical description of New South Wales and Van Diemen's Land," published in the year 1845. After alluding to the Jerusalem and South Esk coal basins of Tasmania, and the Newcastle basin of New South Wales, he writes (page 129):—"With the deposits of the three above described basins we may connect partial outcrops of coal observed in a small valley called the Reedy Valley (the Vale of Clywd), *north of Mount York, and east of Mount Clarence*, and which seemingly belong to the Newcastle basin; a probability, however, rather invalidated by the fact of *the coals overlaying masses of pure bitumen*, a circumstance not discovered to exist elsewhere." It is clear that the deposit thus referred to is the one which was afterwards worked in the Hartley Vale mine.

The catalogue of exhibits, published in 1861, by the International Exhibition Commissioners, contains an article by the late Rev. W. B. Clarke, on "The Coal-fields," from which the following is an extract: "That gentleman (Mr. Gould) has also discovered evidence to prove that the combustible schists or *Dysodile* of the Mersey River, on the north coast of Tasmania, contain zoological fossils of Palæozoic age. In New South Wales beds of similar kinds exist, of which specimens are exhibited from the higher northern slopes of the Liverpool Range, and from the *base of Mount York* in the county of Westmoreland. Examination shows that they are charged with resin (probably not unlike that so abundant in the New Zealand coal), and therefore *they may, perhaps, be valuable as a source for the manufacture of mineral oil.* The specific gravity of some of this substance the author has found to be 1·204. In appearance it is like lignite passing to cannel coal. It ignites readily and burns with a prevailing odour. It is highly conchoidal in fracture, and lies in masses from 6 to 12 inches thick. A somewhat similar substance occurs in the island of Cuba, and is there called Chapapote; but the New South Wales mineral is not so bituminous, and the specific gravity is less."

*Mode of Occurrence.*—Kerosene shale has been found at a number of places in the Upper Coal Measures, and at least two (viz., at Greta and at the head of the Clyde Valley) in the Lower Coal Measures, and in every instance, with, perhaps, one exception, the locality is near the edge of the coal basin. The oil shales of America Creek, near Mount Kembla, though close to the sea coast, are probably, some distance from the edge of the coal basin; but it is notable that they differ materially from the kerosene shale found in other localities, being much more shaly in their structure.

The typical kerosene shale occurs in seams, or lenticular patches of greater or less extent, the largest hitherto found not exceeding a mile in length. At its edges the shale is found to pass into either bituminous or splint coal, or into earthy or stony carbonaceous shale. It is also frequently associated with coal seams either above or below it. The following section of the Joadja Creek kerosene shale seam was measured by the late Mr. C. S. Wilkinson, Geological Surveyor in Charge in 1890:

| Conglomerate roof. | ft. | in. |
|---|---|---|
| Bright bituminous coal ... ... ... | 0 | 6 |
| "Top" kerosene shale.. ... .. ... | 0 | 6 |
| Kerosene shale ... ... .. ... | 2 | 9 |
| "Bottom" shale, hard and splinty ... ... | 0 | 6 |
| Bituminous coal... ... ... ... ... | 0 | 3 |
| Fireclay ... ... ... ... ... ... | 0 | 6 |

The horizon of the Joadja shale, according to the measurement of Mr. John Mackenzie, is 110 feet below the base of the Hawkesbury series.

In 1875 Mr. Wilkinson measured a section of the Hartley Vale seam (*Mines and Mineral Statistics*, 1875, p. 131) as follows:—

| ft. | in. | |
|---|---|---|
| 1 | 6 | —Fireclay. |
| | 1 | —Clayband. |
| | 3 | —Black "casing" |
| | 4 | —"Tops" or impure shale, yielding 40 gallons of crude oil per ton. |
| | 6–8 | —Black shale. |
| | ½–8 | —Band of inferior fuller's earth. |
| | 3 | —Ferruginous black shale. |
| | ½–8 | —Pipeclay. |
| 3 | 2 | —Kerosene shale, yielding up to 80 gallons refined oil per ton. |
| | 10 | —"Bottoms" yielding 60 gallons crude oil per ton. |
| | ½–1 | —Yellow band, fuller's earth. |
| | | Bluish sandstone, with impressions of plants. |

At Joadja Creek, near Mittagong, at Hartley Vale (Mount York), near Mount Victoria, and at Marangaroo, between Bowenfels and

*Photographed by E. F. Pittman.*

CAPERTEE MOUNTAIN.
Retorts recently erected at the New Hartley Co.'s Kerosene Shale Mine.

Wallerawang, beautifully-preserved impressions of the fronds of the fossil plant *Glossopteris* have been found, and in the deposit at the former place *Vertebraria* was also commonly met with.

At Mount Kembla, near Wollongong, a seam of oil shale two feet three inches in thickness was discovered about forty-five feet below the third, or thick seam of coal, in the Upper Coal Measures, and this was the first deposit of the kind to be worked for the manufacture of kerosene. The Kembla mineral, however, differed materially from the Torbanite occurring in other parts of the Colony, and had much more of the character of true shale. Small quantities of kerosene shale were also found at Greta, in the Lower Coal Measures, and in the year 1874, 100 tons were obtained from the Greta Colliery, and 9,000 tons from that of Mount Kembla (*Mines and Mineral Statistics*, p. 56). With the exception of a patch (which has never been worked) at the head of the Clyde Valley, all the other deposits of kerosene shale hitherto found have been in the Upper Coal Measures.

The Hartley Vale deposit was the next to be worked commercially, and in the year 1874, nine thousand tons of the mineral, of the value of £22,500, were raised. This mine has been worked continuously since that date, and is owned by the New South Wales Shale and Oil Company, but very little of the deposit now remains. The seam was found to extend for some distance on both sides of the valley, and it was for a long time believed that denudation had removed the central portion of the deposit; however, after those portions occurring in the sides of the valley had been worked out, prospecting operations revealed the fact that a patch of kerosene shale occurred below the floor of the valley, and it then became evident that this was a portion of the seam originally worked, and had been thrown down as the result of a trough fault. The New South Wales Shale and Oil Company are now working the New Hartley Mine, at Capertee Mountain, where they have erected retorts for the production of crude oil from shale. They have recently entered into a contract to supply the Australian Gaslight Company with one million gallons of crude oil per annum for a period of five years.

Mining operations at the Joadja Creek deposit were commenced in 1876, and during that year 400 tons of shale, valued at £1,200, were extracted. Subsequently a tramway eighteen miles in length was constructed by the owners (The Australian Kerosene Oil and Mineral Company) to connect this mine with the Great Southern Railway line at Mittagong.

In the Joadja Mine, the mineral has also been worked in the mountains bordering both sides of a valley; the deposit is said to have been nearly exhausted, and active mining operations have ceased, though a considerable quantity of shale has been stored near the Mittagong Railway Station.

The maximum length of the largest deposit of shale at Joadja, viz., that on the western side of the valley was about seventy-five chains.

There is reason to believe that this deposit is on a higher horizon than the small patch which has been worked on the east of the valley. Extensive works were established at Joadja for treating the shale, but these have now been dismantled.

The Australian Kerosene Oil and Mineral Company also owned a deposit of shale near Katoomba, Parish of Megalong, County of Cook, but this did not prove to be of very large dimensions, and at the present time they are working the Genowlan Mine, which includes a considerable portion of a deposit of kerosene shale in the Capertee Mountain, between Wallerawang and Mudgee.

The following is a list of the products of the Australian Oil and Kerosene Company (Limited) :—Axle oil, cylinder oil, machine oil, skip grease, axle or carriage grease, mineral tallow, standard grease, transparent grease, kerosene, naphtha, gasolene, blue oil, paraffin candles, benzine, spongaline, engine-cleaning oil, wood-preserving oil, damp repeller.

The complete returns of the shale extracted from the Joadja deposits are not available, but the following table shows the output from 1882 to 1899 inclusive :—

| Year. | Output, in tons. | Average Selling Price. |
|---|---|---|
| | Tons. | £ |
| 1882 ... ... | 28,047 | ........... |
| 1883 ... ... | 29,497 | ........... |
| 1884 ... ... | 19,215 | ........... |
| 1885 ... ... | 17,316 | ........... |
| 1886 ... ... | 28,528 | ........... |
| 1887 ... ... | 28,678 | ........... |
| 1888 ... ... | 26,821 | ........... |
| 1889 ... ... | 27,434 | ........... |
| 1890 ... ... | 29,133 | 82,300 |
| 1891 .. ... | 20,757 | 57,341 |
| 1892 ... ... | 22,073 | 59,137 |
| 1893 ... ... | 13,797 | 40,183 |
| 1894 ... .. | 4,023 | 11,476 |
| 1895 ... ... | 5,461 | 13,606 |
| 1896 ... ... | 2,996 | 7,115 |
| 1897 ... ... | 5,484 | 12,818 |
| 1898 ... ... | 4,781 | 10,159 |
| 1899 ... ... | 7,256 | 15,267 |
| Totals ... ... | 321,297 | 309,402 |

*Origin of Kerosene Shale.*—The peculiar qualities of this valuable mineral, and the fact of its being associated with, and sometimes surrounded by, ordinary coal, have naturally given rise to much speculation as to its origin, and quite a number of theories have been

*Photographed by E. F. Pittman.*

Joadja Township and the Remains of the Australian Kerosene Oil and Mineral Company's Plant.

advanced by different writers. The late Rev. W. B. Clarke wrote as follows:—"It has unquestionably resulted from the local deposition of some resinous wood, and passes generally into ordinary coal, many portions of the same bed in the Illawarra mines exhibiting the impress of fronds of *Glossopteris* as plainly as they are shown on ordinary coal shale. . . . Presuming that the origin above suggested is correct, viz., the occasional occurrence in the ancient deposits of trees of a peculiar resinous constitution, there is no anomaly in finding in one spot a mere patch amidst a coal seam (as in the case of Anvil Creek on the Hunter River), or thick-bedded masses of greater area, as in the coal seams of Mount York, or of America Creek, in the Illawarra, depending on the original amount of drift timber."

The late Mr. C. S. Wilkinson was of opinion that the mineral may also have resulted from the spores of lycopodiaceous plants, as some of the plants in the shale consist of coal. He cited the fact that in the shale from Joadja Creek are stems of *Vertebraria*, forming ordinary coal, embedded in a position perpendicular to the stratification of the shale, thus showing that the hydrocarbonaceous material forming the shale must have been deposited around the *Vertebraria* plant stem whilst the latter was standing erect, and probably during its growth.

The late Mr. Wm. Keene, Examiner of Coal-fields, attributed the formation of kerosene shale to the natural distillation of the hydrocarbons of bituminous coal, owing to the heat produced by intrusions of igneous rocks subsequent to the formation of the Coal Measures.

The late Professor Denton, an American scientist, who visited these colonies some years ago, was of opinion that the deposits were due to the outbursts of deep-seated oilsprings during the Permo-Carboniferous period, and that these springs overflowed into coal swamps, and saturated the peaty material existing there.

Mr. W. A. Dixon, F.C.S., advanced the suggestion that kerosene shale may be the waxy secretion from some of the plants which grew in Permo-Carboniferous times.

Professor T. W. E. David, in a paper read before the Linnean Society of New South Wales, in 1889, reviewed the theories alluded to above, and cited arguments against the majority of them. He recorded the results of his examination, under the microscope, of thin sections of kerosene shale, and of the clayshales associated with it at Homeville. The latter were found to contain abundant spherical bodies, about $\frac{1}{30}$th of an inch in diameter, which he considered were probably sporangia. The kerosene shale was also found to contain, uniformly distributed throughout it, minute resinous-like particles, which he was inclined to believe were originally sporangia, spores, pollen, or seeds. He concluded that the oily character of the mineral might be chiefly due to the local accumulations of showers of minute spores, or sporangia, or seeds, with a certain admixture of peaty material from the swampy ground in which the coal was formed. (This is substantially the opinion advanced in 1879 by the late Mr. C. S. Wilkinson.) Subsequently to the reading of the above paper, Professor David, while examining some Joadja shale under the microscope, observed that in the spherical, resinous-like bodies already referred to, there were numerous aggregations of spindle-shaped or club-shaped bodies having the appearance of the zoospores in some forms of algæ. In an appendix to his paper he therefore stated that "in the present state of our knowledge it may be asserted that kerosene shale was probably formed in lakes; and that it was formed from minute plant bodies, probably either sporangia or (freshwater) algæ."

More recently Professor Bertrand and M. Renault have conducted searching examinations of thin sections of Boghead mineral from Torbane Hill, Autun, and New South Wales, and have arrived at the conclusion that they are algal coals. (*Premieres Notions sur les Charbons de Terre. Bull. Soc. Industrie Min.*, 1897, XI, liv. 3.) They found that with a single exception, the New South Wales kerosene shales are composed of *Reinschia australis*, preserved as orange or yellow bodies in a brown ulmic precipitated matrix.

*Reinschia* is a free alga, the thallus consisting of a single row of cells, forming a hollow sphere, averaging about three mm. in diameter. Messrs. Bertrand and Renault state that these algæ form about ninety per cent. of the mass, and that a certain number of spores are also present. In the Doughboy Hollow (near Murrurundi) kerosene shale they found in addition to *Reinschia*, another alga, viz., *Pila*, which is the main constituent of the Torbane Hill and French Bogheads. The following are extracts from one of Professor Bertrand's papers:—"*Reinschia* represents "*fleurs d'eau.*" Between the thalli of *Reinschia* are some spores and grains of pollen, macerated. . . . . . . The spores and pollen correspond to the rains of sulphur which powder the lakes of Scandinavia and Canada at the flowering time of the forests of *Coniferæ* which surround them. The manner of the accumulation of the thalli shows absolutely still surroundings; there are no mud particles, not even a layer of mica. . . . . As there are no altered algæ I conclude that the vegetable accumulation was formed rapidly, because in such a mass fermentation and decay develop very quickly. On the other hand, there was no interruption between the base and the top of the deposit. I am, therefore, obliged to conclude that the vegetable deposit represents the product of a single period of vegetation, and at the time the waters were shallow—that is to say, the vegetable accumulation which formed the kerosene shale of New South Wales was formed with great rapidity."

The conclusions of Messrs. Bertrand and Renault have not been unanimously adopted, as will be seen from the following extract from a book entitled, "Fossil Plants" (1898), by Mr. A. C. Seward, M.A., F.G.S., Lecturer in Botany in the University of Cambridge :—"The kerosene shale of New South Wales affords the most striking and well-preserved examples of the cellular orange and yellow bodies referred to as the globular thalli of algæ. It is almost impossible to conceive a purely inorganic material assuming such forms as those which occur in the Australian Boghead. On the other hand, it is hardly less easy to understand the possibility of such explanations as have been suggested of the organic origin of these characteristic bodies. The ground mass or matrix of the Boghead is referred to a brown ulmic precipitate thrown down on the floor of a Permian or Carboniferous lake, probably under the action of calcareous water. In this material there accumulated countless thalli of minute gelatinous algæ, which probably, at certain seasons, completely covered the surface of the waters, as the *fleurs d'eau* in many of our fresh-water lakes. In addition to the thalli of *Reinschia* and *Pila*, the Bogheads contain a few remains of various plant fragments, pollen grains, and pieces of wood. Fish scales and the coprolites of reptiles and fishes occur in some of the beds. On a piece of kerosene shale in the Woodwardian Museum, Cambridge, there are two well-preserved graphitic impressions of the tongue-shaped fronds of *Glossopteris Browniana*. There can be little doubt that the beds of Boghead were deposited under water as members of a regular sequence of sedimentary strata. The yellow bodies which form so great a part of the beds are practically all of the same type. *Reinschia* and *Pila* cannot always be distinguished, and it would seem that there are no adequate grounds for instituting two distinct genera, and referring them to different families of recent algæ. Stated briefly, my conclusion is that the algæ of the French authors may be definite bodies; but it is unwise to attempt to determine their affinities within such narrow limits as have been referred to in the above *résumé*. The structure of the bituminous deposits is worthy of careful study, and it is by no means impossible that further research might lead us to accept the view of the earlier investigators, that the brightly coloured organic-like bodies may be inorganic in origin."

In connection with the disputed question of the genesis of kerosene shale it may be stated that a specimen of the mineral, found by the author at Joadja, in July, 1900, appears to have some significance. It is a piece of the weathered outcrop of a seam, and is very laminated, being, in fact, easily separable at the edges into laminæ of about the thickness of a sheet of paper. The interesting feature is that each of these laminæ bears a distinct impression of the fossil *Glossopteris*, so that the mineral has the appearance of being entirely composed of leaves of that plant. Thin sections of the solid portion of the specimen, when examined under the microscope, are seen to contain numerous examples of the orange-coloured *Reinschia* of Bertrand. Portions of the specimen have been forwarded to Professor Bertrand and also to Mr. A. C. Seward.

*List of Localities.*

The following is a list, in alphabetical order, of the localities from which specimens of Kerosene Shale have been received for analysis in the Department of Mines. It should be stated, however, that many of the samples contained much too high a percentage of ash to be of commercial value; at the same time it must be understood, from what has already been said in regard to the mode of occurrence of the mineral, that good shale may occur in the neighbourhood of worthless material, and the names of all the known localities are therefore given for the guidance of prospectors :—

Barigan, Parish of, County of Phillip.
Bathgate, near Wallerawang.
Ben Bullen, near.
Blackheath, near.
Blackman's Crown, near Capertee.
Bundanoon.
Burragorang, Upper.
Capertee, 6 miles from.
,, 9 miles from.
Carlo's Gap, 7 miles from.
Clyde River, head of.
Colo Vale.
Cullen Bulleu.
Doughboy Hollow, near Murrurundi.
Dungaree.
Genowlan, near Capertee.
Gindantherie, Parish of, County of Cook.
Goongal, Parish of, County of Roxburgh.
Greta Colliery.
Gunnedah District.
Hartley Vale.
Ilford, near.
Inverell, near.
Joadja, near Mittagong.
Jervis Bay.
Kanimbla Valley.
Katoomba.
Lawson, near.
Lue, 9 miles from.
Manning River.
Marangaroo.
Megalong, near Katoomba.
Mittagong, near.
Mittagong River.
Morna Point, Port Stephens.
Moss Vale.
Mount Kembla.
Mount Victoria.
Mudgee, 12 miles south of.
,, 18 miles north-west of.
,, 24 miles north-west of.
Murrurundi district.
New Hartley Mine, near Capertce.
Penrith, near.
Picton.
Port Stephens.
Rawdon.
Richmond and Wallerawang, between.
Ruined Castle, Katoomba.
Rylstone.
Scone, near.
Tayar, Parish of, County of Roxburgh.
Thirlmere, 14 miles from.
Ulan Creek, county of Bligh.
Ulladulla.
,, 15 miles north-west of.
Umbiella Creek, Capertee Valley.
,, Parish of, County of Roxburgh.
Wallerawang.
Warragamba.
Wentworth Falls, 8½ miles east of.
Wingecarribee, Parish of, County of Westmoreland.
Wolgan Valley, County of Cook.

*Production of Kerosene Shale.*

The following table shows the quantity and value of Kerosene Shale produced during the years 1865 to 1899:—

| Year. | Quantity. | Average price per ton. | | | Total Value. | | |
|---|---|---|---|---|---|---|---|
| | tons. | £ | s. | d. | £ | s. | d. |
| 1865 ... ... ... ... | 570 | 4 | 2 | 5·47 | 2,350 | 0 | 0 |
| 1866 ... ... ... ... | 2,770 | 2 | 18 | 10·48 | 8,150 | 0 | 0 |
| 1867 ... ... ... ... | 4,079 | 3 | 14 | 9·21 | 15,249 | 0 | 0 |
| 1868 ... ... ... ... | 16,952 | 2 | 17 | 7·11 | 48,816 | 0 | 0 |
| 1869 ... ... ... ... | 7,500 | 2 | 10 | 0·00 | 18,750 | 0 | 0 |
| 1870 ... ... ... ... | 8,580 | 3 | 4 | 3·18 | 27,570 | 0 | 0 |
| 1871 ... ... ... ... | 14,700 | 2 | 6 | 3·91 | 34,050 | 0 | 0 |
| 1872 ... ... ... ... | 11,040 | 2 | 11 | 11·91 | 28,700 | 0 | 0 |
| 1873 ... ... ... ... | 17,850 | 2 | 16 | 6·55 | 50,475 | 0 | 0 |
| 1874 ... ... ... ... | 12,100 | 2 | 5 | 1·48 | 27,300 | 0 | 0 |
| 1875 ... ... ... ... | 6,197 | 2 | 10 | 2·22 | 15,500 | 0 | 0 |
| 1876 ... ... ... ... | 15,998 | 3 | 0 | 0·00 | 47,994 | 0 | 0 |
| 1877 ... ... ... ... | 18,963 | 2 | 9 | 0·81 | 46,524 | 0 | 0 |
| 1878 ... ... ... ... | 24,371 | 2 | 6 | 11·40 | 57,211 | 0 | 0 |
| 1879 ... ... ... ... | 32,519 | 2 | 1 | 1·96 | 66,930 | 10 | 0 |
| 1880 ... ... ... ... | 19,201 | 2 | 6 | 7·03 | 44,724 | 15 | 0 |
| 1881 ... ... ... ... | 27,894 | 1 | 9 | 2·59 | 40,748 | 0 | 0 |
| 1882 ... ... ... ... | 48,065 | 1 | 15 | 0·00 | 84,114 | 0 | 0 |
| 1883 ... ... ... ... | 49,250 | 1 | 16 | 10·77 | 90,861 | 10 | 0 |
| 1884 ... ... ... ... | 31,618 | 2 | 5 | 7·86 | 72,176 | 0 | 0 |
| 1885 ... ... ... ... | 27,462 | 2 | 8 | 11·62 | 67,239 | 0 | 0 |
| 1886 ... ... ... ... | 43,563 | 2 | 5 | 10·79 | 99,976 | 0 | 0 |
| 1887 ... ... ... ... | 40,010 | 2 | 3 | 10·43 | 87,761 | 0 | 0 |
| 1888 ... ... ... ... | 34,869 | 2 | 2 | 2·66 | 73,612 | 0 | 0 |
| 1889 ... ... ... ... | 40,561 | 1 | 18 | 3·55 | 77,666 | 15 | 0 |
| 1890 ... ... ... ... | 56,010 | 1 | 17 | 2·07 | 104,103 | 7 | 6 |
| 1891 ... ... ... ... | 40,349 | 1 | 18 | 8·77 | 78,160 | 0 | 0 |
| 1892 ... ... ... ... | 74,197 | 1 | 16 | 8·16 | 136,079 | 6 | 0 |
| 1893 ... ... ... ... | 55,660 | 1 | 16 | 4·44 | 101,220 | 10 | 0 |
| 1894 ... ... ... ... | 21,171 | 1 | 10 | 0·28 | 31,781 | 5 | 0 |
| 1895 ... ... ... ... | 59,426 | 1 | 5 | 3·78 | 75,218 | 18 | 8 |
| 1896 ... ... ... ... | 31,839 | 1 | 1 | 5·81 | 34,201 | 18 | 0 |
| 1897 ... ... ... ... | 34,090 | 1 | 3 | 9·91 | 40,611 | 15 | 0 |
| 1898 ... ... ... ... | 29,689 | 1 | 1 | 5·34 | 31,834 | 0 | 0 |
| 1899 ... ... ... ... | 36,719 | 1 | 2 | 2·83 | 40,823 | 5 | 0 |
| | 995,832 | 1 | 18 | 3·95 | 1,908,482 | 5 | 2 |

# GRAPHITE.

*Graphite or Plumbago.*—Composition carbon, often impure from the presence of sesquioxide of iron, clay, &c.; crystallises in six-sided tabular crystals; commonly in embedded foliated masses; also columnar, or radiated; scaly or slaty; granular to compact; earthy; colour, iron-black to dark steel-gray; lustre metallic, sometimes dull, earthy; hardness, 1–2; specific gravity, 2·09–2·23; has a greasy feel, and leaves a black streak on paper, by which it can be distinguished from molybdenite, which gives a grayish-green streak. The two minerals can also be distinguished from one another when heated in a closed tube, as molybdenite gives off sulphurous fumes, while graphite remains unaltered.

*Mode of occurrence of Graphite.*—The world's supply of graphite is chiefly derived from Ceylon, Austria, Siberia, Italy, Japan, the United States, and England (Cumberland). According to Dr. Ernest Weinschenk, all graphite deposits may be divided into two groups, and these, again, into several divisions, according to type localities. His classification is as follows:—

*I. Vein-like occurrences.*—These, generally speaking, are the purer of the two, and are, therefore, of the greater industrial importance:—

(*a*) *Ceylon.*—Veins of scaly or fibrous graphite intersect granite or closely associated rocks. The country rock is often highly decomposed, and then consists mainly of kaolin and similar decomposition products.

(*b*) *Borrowdale* (Cumberland, England).—Fine scale graphite in veins in greenstone-porphyry. The gangue is chiefly calc-spar, brown-spar, and quartz, in which occur nests and lumps of very fine graphite, especially suitable for the manufacture of pencils.

(*c*) *Batugol* (Province of Irkutsk, Siberia).—Finely fibrous graphite, purer than that of Borrowdale. The veins run through a granite or dioritic rock, while in the closely adjoining limestone, which is altered by contact metamorphism, are great lumps of pure graphite, suitable for pencils only.

*II. Bed-like Occurrences.*

(*a*) *Passau.*—In the most easterly corner of Bavaria, bounded on the south by the Danube, and on the east by the Austrian frontier, gneissose rocks occur impregnated with scaly graphite, which at times appears as lenticular masses of rich mineral. These are found chiefly in the immediate neighbourhood of intercalated beds of granular limestone, altered by contact metamorphism. Both the graphite-bearing rock and its near neighbours are much decomposed, so that kaolin and other decomposition products are found in intimate association with the graphite deposits. The genetic connection of these with the Ceylon type is very close.

(*b*) *Schwarzbach–Krumau* (Bohemia).—This appears to be the most widespread of any. The lenticular form of the deposits, their geological relationship with intercalated limestones, their frequent association with kaolin and other decomposition products, connect them closely with the Passau type, from which they are differentiated by the more compact, less crystalline character of the graphite.

(*c*) *Paltenthal–Kaisersberg.*—On the northern border of the central zone of the Styrian Alps is a highly metamorphosed system of Carboniferous shales, clay-slates, limestones, and conglomerates with coal seams, the coal of which has passed into graphite, which preserves completely, in some cases, the appearance of the coal from which it is derived. It is very compact, very pure, and often extremely hard. It is used for crucibles.

*Artificial Graphite.*—The following is an extract from Rothwell'a *Mineral Industry*:—"An important event in the graphite industry of the United States in 1898 was the manufacture of an artificial graphite direct from coke, which it is thought can be put on the market at a price to compete with the natural product. During the year about 200,000 ℔. of carbon rods were graphitized for electrolytic alkali manufacturers in the United States, England, and Germany. This reversed the direction of the trade in carbon electrodes, Europe now buying in America, whereas formerly America bought in Europe. It is anticipated that in the near future nearly all electric motor brushes will be made out of this artificial graphite, which has been found to possess not only high lubricating qualities, but also an exceedingly high conductivity. The artificial graphite can also be substituted for the natural product in the manufacture of lead pencils, stove polish, and paint. This business was inaugurated by the Carborundum Co., operating under patents granted to E. G. Acheson, but now it has been taken over by the Acheson Graphite Co., which intends to erect works at Niagara Falls, N.Y."

"According to the Acheson patents, carbon in the form of coke, charcoal, or lampblack is granulated, mixed with an oxide or metallic salt, such as oxide or sulphate of iron, moistened with water containing a little sugar or other binding material in solution, and pressed into the desired shape. These shapes are then placed in an electric furnace, embedded in fine carbon, which is surrounded by a layer of amorphous carborundum, sufficiently thick to prevent the rapid radiation of heat. The current is turned on the furnace, and under the influence of the high temperature the carbon is more or less completely graphitized; it has been found advisable to leave a portion of the carbon unconverted, since this tends to make the article stronger."

In the 1889 volume of the *Mineral Industry*, the following additional remarks occur:—"The use of graphitized anodes and electrodes has shown a remarkable increase, for the trade, which amounted to 200,000 lb. in 1898, reached 405,870 lb. in 1899, and the year closed with indications that 1900 will double the large output of 1899."

*Uses of Graphite.*—The present uses of graphite include the manufacture of pencils, crucibles, stove polish, foundry facing, paint, motor and dynamo brushes, anti-friction or lubricating compounds, electrodes for electro-metallurgical work, conducting surfaces in electrotyping and covering the surfaces of powder grains.

For most of these purposes it is used in the natural impure state, while for others it is necessary to render it quite pure and free from grit. The general method of purification is that worked out by Brodie, and consists in first grinding or otherwise reducing the graphite to a fine state of subdivision, washing out the heavier impurities, mixing fourteen parts with one part of potassium chlorate, and two parts of concentrated sulphuric acid, heating on a water-bath for some hours, washing thoroughly, and subsequently roasting at a red heat. If silica be present, the process is supplemented by a treatment with hydrofluoric acid.

In 1899, the consumption of graphite in the United States amounted to 45,218,608 lb., valued at 2,135,953 dollars.

Composition of Foreign Graphites. (*Mineral Industry.*)

| | Carbon—per cent. | Ash—per cent. | Volatile matter—per cent. |
|---|---|---|---|
| Canadian (from veins) ... ... ... | 99·67 | 0·14 | 0·18 |
| ,, ,, ... ... ... | 97·62 | 1·78 | 0·59 |
| ,, ,, ... ... ... | 99·81 | 0·08 | 0·11 |
| ,, ,, ... ... ... | 99·76 | 0·13 | 0·11 |
| Ceylon ,, ... ... ... | 99·79 | 0·05 | 0·16 |
| ,, ,, ... ... ... | 99·68 | 0·21 | 0·11 |
| ,, ,, ... ... ... | 98·82 | 0·28 | 0·90 |
| ,, ,, ... ... ... | 99·28 | 0·41 | 0·30 |
| German (impregnations in gneiss) ... | 53·78 | 42·95 | 3·28 |
| ,, ,, ,, ... ... | 31·72 | 63·26 | 5·02 |
| ,, ,, ,, ... ... | 34·54 | 62·01 | 3·45 |
| ,, ,, ,, ... ... | 54·49 | 41·85 | 3·66 |
| ,, ,, ,, ... ... | 36·22 | 61·80 | 2·88 |
| ,, ,, ,, ... ... | 45·25 | 52·05 | 2·70 |

| | Graphite. | Soluble in Hydrochloric Acid. | Insoluble. | Hydroscopic Water. |
|---|---|---|---|---|
| Canadian (disseminated in limestone) | 27·52 | 17·54 | 54·90 | 0·04 |
| ,, ,, ,, | 22·38 | 19·47 | 56·41 | 1·74 |
| ,, ,, ,, | 23·80 | 21·28 | 53·74 | 1·18 |
| ,, ,, ,, | 30·52 | 2·47 | 66·87 | 0·13 |

At Passau, in Germany, the mineral occurs in a bed of variable thickness (maximum sixteen feet) in felspathic gneiss, and graphite also occurs in the latter rock in the form of small grayish-black scales, partly taking the place of mica. The mineral is amorphous and of poor quality. It is dressed in a crude manner and with great loss. The graphite, as brought from the mine, is separated according to its hardness and purity into several grades. The softer varieties are ground in an ordinary mill with horizontal stones, while the harder are first crushed in a stamp battery. During the grinding the elastic, very thin and soft scales of graphite arrange themselves parallel with the surfaces of the mill-stones, and so preserve their flat forms, while the hard brittle pieces are pulverized. The ground product is then passed over a fine silk gauze-sieve on which the scales of graphite remain, while the fine flour, or waste, passes through. The best raw material contains 53·8 per cent. of graphite, the dressed product 89·2 per cent., and the waste from 22·3 to 36·8 per cent. (*Mineral Industry.*)

*The occurrence of Graphite in New South Wales.*—Graphite has not, as yet, been found in New South Wales in a sufficiently pure state to be of value for the manufacture of pencils; nevertheless, deposits are known to occur which are suitable for other purposes for which this mineral is employed, and which appear to compare favourably with some of the beds of graphitic material now being worked in Germany and Canada.

The principal deposit known consists of a bed of graphite-bearing shale, about six feet in thickness, which occurs about five miles to the eastward of Undercliff Station, and about twelve miles from Wilson's Downfall, in the County of Buller. This bed is inclined at an angle of about 45°, and is interstratified with schists, sandstones, and claystones, which are probably of Carboniferous age. It is situated close to the junction of these sedimentary rocks with intrusive granite.

Several attempts have been made to work the Undercliff deposit, and parcels of the graphite have been sent away at different times for experimental purposes, one parcel of twenty-seven tons realising at the rate of £1 per ton, which, however, was not remunerative.

A sample of one ton was sent to the Chicago Exhibition, whence it was ultimately forwarded to some large works at Massachusetts for trial. In reference to this sample, Mr. L. S. Brown, of the Springfield Facing Company, Massachusetts, made the following report:—"We are positive that it would make a very good facing, and could be used to advantage wherever German 'lead' (plumbago) is used in the manufacture of foundry facings. It is true that it would probably be impossible to ship it to this country at the price we pay you, as we can buy a powdered German lead at 1¼ cent in New York, or an Italian lead, which closely resembles it, at about sixteen dollars per ton. On any work in the foundry where the facing is used wet—such as dry sand or cores—it would be a very good article indeed, and in any market you could reach we think it would pay to have same used."

The following analyses of samples of graphite have been made at different times in the Laboratory of the Department of Mines:—

| Date. | Locality. | Description of Mineral. | Carbon. | Ash. | Moisture. | Silicia. | Alumina. | Lime. |
|---|---|---|---|---|---|---|---|---|
| 1888 | Grafton ... | Felspathic graphite ... | 46·28 | ... | 8·77 | 27·96 | 15·93 | 0·96 |
| ,, | Mudgee ... | Plumbago clay ... | 34·40 | 58·25 | 7·35 | ... | ... | ... |
| 1890 | Undercliff ... | Inferior graphite ... | 31·76 | 59·58 | 8·66 | ... | ... | ... |
| ,, | ,, ... | ,, ,, ... | 28·60 | 63·50 | 7·90 | ... | ... | ... |
| 1894 | New England | Graphitic clay ... | 33·83 | 58·84 | 7·33 | ... | ... | ... |
| 1895 | Fairfield ... | Graphite ... ... | 47·12 | 46·27 | 6·61 | ... | ... | ... |
| ,, | Hillgrove ... | Graphite disseminated through a soft rock. | 12·44 | 75·68 | 11·88 | ... | ... | ... |

Graphite, in very minute brilliant plates, is a common constituent of the Hawkesbury Sandstones in the neighbourhood of Sydney, the Blue Mountains, and elsewhere; its proportion to the mass of the rock is, however, insignificant.

In the Annual Report of the Department of Mines for 1880, is a report by Mr. E. H. Becke, of Port Macquarie; it contains the following remarks in reference to graphite:—"Tobin's Creek abounds in quartz reefs, and strange to say, not one of these has even had a pick put into it. There are several reefs about five miles from Tobin's, at a place called 'The Cells,' with veins of plumbago running alongside of them. These veins are charged with pyrites, such veins being composed as above, with rotten quartz. I am also informed that at Cowell Creek there is a very heavy deposit of the above mineral."

According to Professor Liversidge (*Minerals of N. S. Wales*), graphite also occurs at the following localities, viz., at the head of the Abercrombie River, with quartz, iron pyrites, and pyromorphite; in small radiating masses in the granite at Dundee, in New Valley, and near Tenterfield; at Bungonia (doubtful); at Panbula, near Eden, in quartz; at the Cordeaux River, near Mount Keira; and at Plumbago Creek, near the junction of Timbarra Creek, County of Drake.

*Production of Plumbago (Graphite.)*

| Year. | Quantity. | Value. |
|---|---|---|
| | Tons. | £ |
| 1894 ... ... .. | 17 | 68 |
| 1895 ... ... ... | .......... .. | ............ |
| 1896 ... ... ... | 80 | 160 |
| 1897 ... ... ... | ............ | ............ |
| 1898 ... ... ... | ............ | ............ |
| Totals ... ... | 97 | 228 |

# DIAMONDS.

*Diamond*, composition pure carbon; crystallises in the Isometric System, in modified octahedrons and rhombic dodecahedrons, the faces being often much curved, and the crystals often distorted; colour white or colourless, sometimes exhibiting pale shades of yellow, red, orange, green, blue, and brown; also deep yellow and sometimes black; usually transparent, also translucent, and opaque; lustre adamantine to greasy, sometimes dull; hardness 10; specific gravity 3·516–3·525 crystals; 3·499–3·503 bort; 3·15–3·29 carbonado.

The diamond is most easily recognised by its hardness, which is greater than that of any other mineral, its extraordinary lustre, and its crystalline form. It should be borne in mind, however, that although it is the hardest substance known, it is also comparatively brittle. Many valuable diamonds have been destroyed in consequence of an erroneous belief, which was promulgated by Pliny, that a genuine diamond, when placed on an anvil, can not be broken by a blow with a hammer. The real test of the hardness of a diamond is that it will scratch any other mineral, and can not, in turn, be scratched by any other. The diamond can be burned in oxygen, with the production of carbonic acid gas. Another peculiarity of the diamond is that it is transparent to the Rontgen rays. Owing to this property it can be readily distinguished from imitation gems, as the glass of which the latter are made, is almost perfectly opaque to the rays..

The remarkable lustre and hardness of the diamond are also the properties which determine its value as a gem. The *quality* of the lustre is described as adamantine, its high capacity for reflecting and refracting light allow of the *intensity* of the lustre being increased when the stone is cut. Thus in the case of a brilliant the facets on the lower side are given such an inclination as will cause them to reflect all the light falling upon them. Professor Sir William Crookes, F.R.S., says: "A well cut diamond should appear opaque by transmitted light, except at a small spot in the middle where the table and culet are opposite. All the light falling on the front of the stone is reflected from the facets, and the light passing into the diamond is reflected from the interior surfaces and refracted into colours when it passes out into the air, giving rise to the lightnings and coruscations for which the diamond is supreme above all other gems.

The variety known as *Bort*, or *Boart*, occurs rather imperfectly crystallised in somewhat rounded forms with rough exterior; its colour varies from grayish to blackish, and it is translucent rather than transparent, so that it is valueless as a gem. It is used in a powdered state for polishing other diamonds.

*Carbonado* or *carbon* is a black and opaque uncrystallised diamond. It is obtained chiefly in the Province of Bahia, in Brazil. Its hardness is quite as great as, if not greater than, that of the crystallised variety, and it is less brittle, hence it is of great value for diamond drills. Carbonado contains from ·24 to 2·03 per cent. of impurity or ash.

Hitherto the chief sources of the diamond have been the mines of India, Brazil, and South Africa. In the first named country they were worked from very early times, principally in three regions, viz. :—(1.) In the Madras Presidency, embracing the districts of Kadapah, Bellary, Karnul, Kistna, and Godavari (2.) A large tract between the Mahanadi and Godavari rivers. (3.) A region in Bundelkhand, especially near the town of Panna.

The diamonds of India were found both in alluvial deposits and in a quartzose conglomerate; the latter contains numerous fragments of an older sandstone, known as the Semri Sandstone, and it has been suggested by some geologists that this Semri Sandstone is the original matrix of the diamonds. The diamond is also said to have been found *in situ* in a peridotite vein at Bellary, in Madras Presidency.

The Indian mines which were, for a long period, extremely productive, are now understood to be nearly exhausted.

In Brazil, diamond-mining commenced early in the eighteenth century, and a large output was maintained for many years, but at the present time the yield is comparatively insignificant. The most productive region was that in the neighbourhood of Diamantina, in the Province of Minas Geraes. It is situated on a range separating the Sao Francisco River from its tributaries. The diamonds were obtained in quartz-pebble wash, and also to some extent in a laminated rock, termed *itacolumite*, consisting of quartzose hydromica schist, which is noted for its flexibility when cut in thin slabs.

The alluvial deposits are of two kinds known as river washings (*servicos do rio*), and prairie washings (*servicos do campo*), the latter occurring on the high ridge, and containing quartz fragments which are less waterworn than those of the river washings. In the river washings the diamonds were found most abundantly in large pot-holes known as *Caldeiroes*.

In South Africa diamonds were discovered accidentally in the year 1867. A farmer was visiting the house of a friend in the Hope Town district, and noticed some children playing with a bright stone; on his expressing his admiration for it, he was presented with it by the mistress of the house. It was subsequently given by him to a trader, who had it examined by experts, when it was recognised as a diamond worth £500. In 1869 a large diamond, known as the Star of South Africa, and worth £11,000, was found near the Vaal River, and in 1870 the celebrated "Dry Diggings," in the vicinity of the present town of Kimberley, were discovered.

The earliest worked diamond-mines in South Africa were in the waterworn gravels along the banks and bed of the Vaal River, and it was eventually ascertained that the gravels were diamond-bearing for a considerable distance, viz., from the town of Potchefstroom to the junction of the Vaal with the Orange River, and along the later as far as Hope Town. The most productive mines were situated on the Vaal, between Klip Drift and the junction of the Hart River. The river gravels have, however, been almost worked out, and the production of diamonds from them is now insignificant.

The so-called "dry-diggings," which are now the source of the greater part of the world's supply of diamonds, were discovered in the year 1870. There are four distinct mines of this class in the neighbourhood of Kimberley, viz., De Beers, Kimberley, Du Toit's Pan, and Bultfontein Mines, and a good many others have since been found within a region having a maximum length of four hundred and fifty miles by a width of about two hundred and fifty miles. Their formation is so distinct from that of any previously known diamond-bearing formation, and appears to bear so directly upon the question of the origin of the gem, that an account of them will be of interest to the prospectors of New South Wales.

The diamonds at Kimberley occur in volcanic pipes, the surface areas of which are more or less circular or oval in form, while the rocks bounding them are shales, horizontal, or nearly so, in their stratification, except just at their junction with the circumference of the pipes, where the edges of the shales are bent sharply upwards. The material with which the pipes are filled, and through which the diamonds are scattered is the same in all the mines, and distinctly shows that they are of volcanic origin.* Near the surface this material was more or less decomposed and was of a light yellow colour; it was known amongst the miners as *yellow ground.* As the workings advanced in depth, however, the yellow material was found to give place to harder rock of a dark greenish-blue colour, and this was locally known as *blue ground.* It was at first thought by the miners to be bed-rock; but was subsequently found to be similar in composition to the *yellow ground* (but less decomposed), and to also contain diamonds. Through its serpentinous base are scattered particles, fragments, and large masses of shale, and dolerite, and occasional fragments of chloritic schist, micaceous schist, diorite, eclogite, and granite. The fragments are, as a rule, angular, or subangular, and the edges of the shale show no signs of fusion. The following minerals are also present, viz., bronzite, diallage, vaalite (an altered mica).

* The first to publish a scientific description of the Kimberley deposits and to recognise them as of volcanic origin was Professor E. Cohen (*Neues Jahrbuch*, 1872, p. 857). He was followed by Mr. E. J. Dunn, who contributed a paper to the Geological Society of London in December, 1873, in which he expressed similar views.

garnet, calcite, chrome-diopside, magnetite, ilmenite, smaragdite, zircon, and pyrite. There has been much difference of opinion amongst European and American geologists as to the origin of this rock; but it is now generally regarded as a serpentinized volcanic breccia or agglomerate.

Disseminated through the volcanic breccia the diamonds occur, and these vary in size from microscopic crystals upwards. The largest diamond the world has ever seen was found in the year 1893 in the Jagersfontein pipe, near Fauresmith, in the Orange River colony. It weighs 969½ carats,* or more than half a pound troy. It is of irregular shape, and is about three inches in maximum length, and about two inches in width. Its colour is the perfection of blue-white, but it has a small black spot in the centre. Its value cannot possibly be estimated with any accuracy.

It is noteworthy that a considerable proportion of the diamonds found in these pipes have been fractured, and many of the whole diamonds extracted from the mines are in such a state of tension that they burst into fragments after being exposed to ordinary atmospheric conditions.

The volcanic pipes generally rise slightly above the surface of the surrounding country, forming a small rounded hill or kopje; this is not, however, an invariable feature, and the surface configuration will necessarily be governed by atmospheric denudation.

At the present time the workings in the Kimberley Mine have penetrated to a depth of over eighteen hundred feet, and consequently an instructive section of the rocks forming the walls of the pipe is available.

The surface of the country is covered with red soil from one to five feet in depth, and under this is a sheet of much decomposed basalt from twenty to ninety feet in thickness. Below the basalt are beds of black carbonaceous shales, containing a considerable quantity of iron pyrites in thin seams of impure coal. These shales are very liable to spontaneous combustion—in fact, at the Kimberley Mine they have been burning for some years. Underlying the shales is a very hard amygdaloidal rock, composed of plagioclase, augite and olivine, and identified as diabase; in the Kimberley Mine a thickness of four hundred and four feet of this diabase was penetrated, and it was in turn succeeded by quartzite. In other parts of South Africa diamond-bearing pipes are known to intersect rocks which differ entirely in character from those at Kimberley, so that the geological age of the country is no guide to the prospector when searching for these interesting deposits.

The Kimberley Mines were originally worked "open cast," the pipes being divided up into a number of small holdings or claims of thirty feet square. This method was extremely unsatisfactory, for several reasons. In the first place it was a matter of great difficulty to maintain the boundaries between adjoining claims (most of which were working at

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* A carat weight is equal to 3·162 troy grains.

# SECTION OF
# THE KIMBERLEY DIAMOND MINE
## A VOLCANIC PIPE

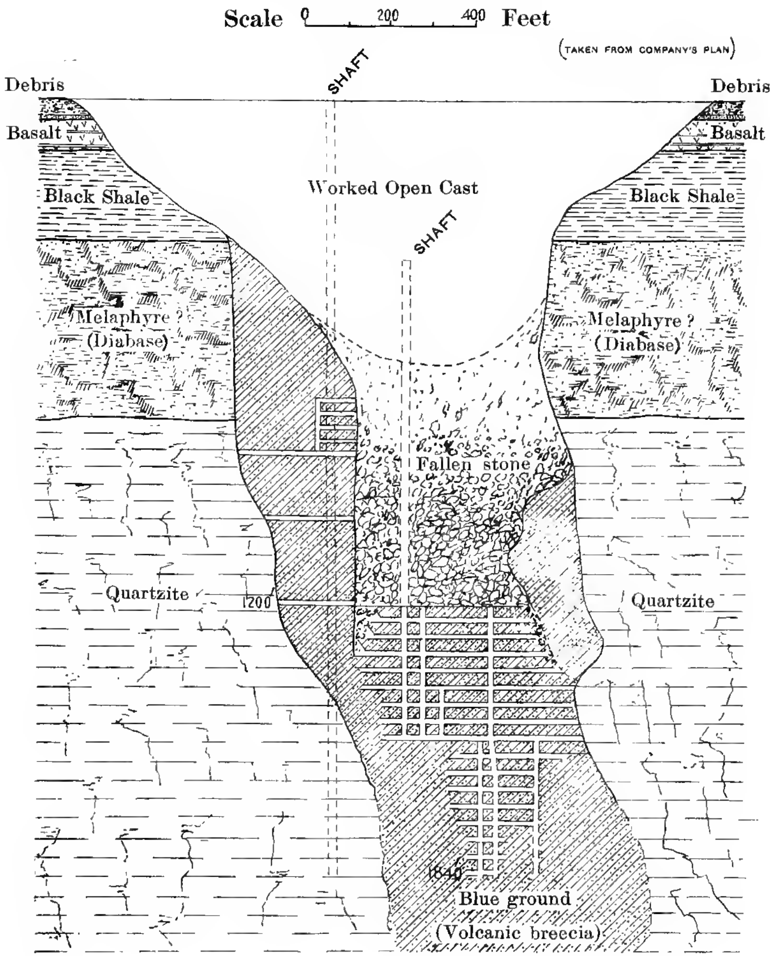


*Photo-lithographed by*
*W. A. Gullick, Government Printer,*
*Sydney, N.S.W.*

different depths), and as a natural consequence the disputes were interminable. Secondly, owing to the perpendicular manner in which the claims were worked they soon became unsafe, and very frequently large masses of high ground subsided, so much so that in 1872 they threatened to convert the whole of the workings into ruins. Then, again, as the deeper or blue ground was reached, and was found to be as rich as that previously worked, the problem of how to prevent over-production, with the certain result of a serious fall in the market value of diamonds, had to be faced.

The difficulties were all overcome in the year 1880 by the formation of a powerful company called the De Beers Consolidated Mines, which, by purchase and amalgamation, obtained control over practically the whole of the industry. This Company, in 1898, employed 1,819 whites, and 10,378 natives, and during the twelve months ending 30th June, 1898, they raised 3,951,414 loads of blue ground for a yield of 2,792,606 carats of diamonds, which realised by sale £3,647,874. During the same period dividends amounting to £1,579,582 were paid, or at the rate of 40 per cent. on the capital of the company.

The work is now all carried out by underground tunnels connecting with shafts excavated through the solid rock at the side of the pipe, and the difficulties and dangers of the old system of working are thus entirely avoided.

The areas of the four principal Kimberley mines were as follows:— De Beers, 22 acres; Kimberley, 33 acres; Du Toit's Pan, 45 acres; Bultfontein, 36 acres. At the level of the blue ground the pipes had contracted considerably, so that the area of De Beers Mine was 10·12 acres, of which 5·97 acres were worked; and the area of Kimberley Mine was 4·55 acres, of which 2·69 acres were worked.

The average yield of diamonds per load of blue ground is as follows:— Kimberley, $1\frac{1}{4}$ to $1\frac{1}{2}$ carats, De Beers $1\frac{1}{5}$ to $1\frac{1}{3}$ carats, Du Toit's Pan, $\frac{1}{6}$ to $\frac{1}{2}$ carat, and Bultfontein, $\frac{1}{3}$ to $\frac{1}{2}$ carat. The two last-named mines are not being worked by the Company, though it was considered necessary to purchase them for the purpose of preventing over-production.

The diamonds from the different pipes in South Africa are said to possess distinguishing features which enable buyers to tell the locality from which any parcel of stones has been obtained. In reference to this matter, Sir William Crookes, F.R.S., writes:—"De Beers and Kimberley Mines are distinguished by large yellowish crystals. Du Toit's Pan yields mainly coloured stones, while Bultfontein, half a mile off, produces small white stones, occasionally speckled and flawed, but rarely coloured. Diamonds from the Wesselton Mine are nearly all irregular in shape; a perfect crystal is rare, and most of the stones are white; few yellow. Diamonds from the Leicester Mine have a frosted, etched appearance; they are white, the crystallisation irregular (cross-grained), and they are very hard. The newly-discovered Newlands Mines, in Griqualand West, are remarkable for the whiteness of their diamonds and for their many perfect octahedral crystals. Jagersfontein stones, in the Orange Free State, take the prize for purity of colour and brilliancy, and they show that so-called 'steely' lustre characteristic of old Indian gems. Stones from Jagersfontein are worth nearly double those from Kimberley and De Beers."

Dana mentions that diamonds occur in connection with an eruptive pegmatite in South Africa.

*Diamonds in Meteorites.*—In connection with the genesis of the diamond, the fact of its occurrence in extra-terrestrial substances (meteorites) is of peculiar interest. In 1846 Haidinger described a cubic form of graphite in an iron meteorite from Arva, in Hungary, and Gustave Rose suggested that the crystals were pseudomorphs after diamond. The stony portion of the Arva meteorite consisted almost entirely of the mineral peridot, and there is thus an analogy between this occurrence and that of the South African diamonds which were found in peridotite.

Again, in 1888, Messieurs Jerofeieff and Latschinoff discovered graphite, which had the hardness and form of the diamond, in a meteorite from Novo Urei, in Russia.

In 1889, E. Weinschenk discovered minute grains of a transparent substance in the Arva meteorite, and on making careful tests of these he found that they were sufficiently hard to scratch a ruby, and that when burned in oxygen they produced carbonic acid gas.

Precisely similar crystals to those found in the Arva meteorite were subsequently identified by Mr. Fletcher in two iron meteorites, one of which fell at Youndegin, in Western Australia, and the other at Crosby's Creek, in the United States.

In 1891, Dr. A. E. Foote collected a quantity of meteoric iron at Cañon Diablo, in Arizona, and subsequently announced that he had discovered minute diamonds in it. His attention was first attracted to them owing to the extreme difficulty he experienced in cutting the meteoric iron, the tools employed in the operation being very much injured owing to the presence of something much harder than iron.

In 1893, Dr. O. W. Huntingdon dissolved a considerable quantity of the Cañon Diablo meteoric iron, and from the residue he succeeded in separating some minute crystals (hexakis-octahedrons), which he identified in all their chemical and physical properties as diamonds.

*The Artificial Production of the Diamond.*—For many years it was the dream of chemists to produce the diamond by artificial means, and this has now been successfully accomplished by several scientists, each of whom adopted a different method. The resulting diamonds, however, in each case were extremely minute, and there does not appear to be any immediate probability that the discovery can be utilised for the production of stones of any value as gems.

The first to produce artificial diamonds was Mr. J. B. Hannay, a Scotch chemist. In 1880 he contributed a paper to the Royal Society of London, in which he gave the details of his experiment. It consisted of heating in a reverberatory furnace a very strong, hermetically closed wrought-iron cylinder containing four grammes of lithium, and a mixture of 90 per cent. of rectified bone oil and 10 per cent. of paraffin spirit (hydro-carbon). After being heated for some hours the cylinder was allowed to cool, and was then cut open. It contained a hard black mass consisting of iron and lithium, and this was found to contain extremely minute diamonds. Mr. Hannay explained that when a gas containing carbon and hydrogen is heated, under pressure, in the presence of certain metals, its hydrogen is attracted by the metal and its carbon set free; and that the latter (under the influence of heat and great pressure, and in the presence of a stable compound containing nitrogen) is so acted upon by the nitrogen compound (bone oil) that it is obtained in the clear transparent form of the diamond. Mr. Hannay's experiments were both expensive and dangerous, owing to the difficulty of obtaining cylinders sufficiently strong to withstand the pressure. The iron tubes burst in a majority of cases, and out of eighty experiments performed by him only three successful results were obtained.

In 1888 the Hon. C. A. Parsons contributed to the Royal Society of London a description of an experiment by which he obtained a somewhat similar result. In a massive cylindrical steel mould he placed a carbon rod, surrounded by layers of lime, sand, and coke-dust. The contents of the mould were subject to hydraulic pressure (communicated by a plunger which fitted into the mould), and they were, at the same time, electrically heated by a large current which was made to pass along the carbon rod. He stated that in from ten to thirty minutes the current was generally interrupted by the breaking or fusing of the rod, or by the action of the lime in dissolving it at the top or bottom. On opening the mould, when it had cooled a little, the silica usually appeared to have fused to an egg-shaped mass, and mixed somewhat at the ends with the lime; the surface of the carbon appeared acted on, and sometimes pitted and crystalline in places; silica adhered to the surface, and beneath, when viewed under the microscope, there appeared a globular cauliflower-like formation of a yellowish colour, resembling some specimens of *bort.* The minuteness of the particles rendered it difficult to determine all the distinctive features of this substance, but it was proved to be harder than the ruby, and there appeared to be very little doubt that it consisted of crystalline carbon.

Perhaps the simplest and most ingenious method yet devised for the production of diamonds was that described in 1893 by the celebrated French chemist, M. Moissan. He melts iron, in contact with charcoal, by means of an electric current. The iron in a short time saturates itself with carbon; the current is then stopped, and the surface of the iron is suddenly cooled by plunging it into water. A crust of solid iron is thus formed on the outside, and this acts as an immovable envelope for the still molten iron in the interior. Iron expands at the moment it passes from the liquid to the solid state, but the interior iron in this case is prevented from expanding, as it solidifies, by reason of the solid crust which envelopes it. It consequently exerts an enormous pressure, and under the influence of this pressure the dissolved carbon crystallises out from the iron in the form of minute diamonds.

M. Moissan, in his experiment, employed pure iron—free from sulphur, phosphorus, and silicon—and this he packed in a carbon crucible with charcoal made from sugar. The crucible was then placed in an electric furnace, and subjected to the heat of an arc formed close above it between carbon poles; a current of 700 ampères was used with a pressure of 40 volts. The temperature obtained was about 4,000° C., and after being exposed to this for a few minutes, the crucible was held under cold water until it sank below a red heat.

The actual operation of making diamonds by M. Moissan's process only occupies a few minutes, but their separation from the enclosing mass is a very tedious process, occupying nearly a fortnight. It is first necessary to dissolve all the iron in hot nitro-hydrochloric acid; and when this is accomplished there is a bulky residue, consisting of graphite, flaky carbon, carbonado, fragments of crystalline diamond, with possibly some corundum, and carbide of silicon (carborundum). The residue is treated with strong boiling sulphuric acid, with the addition of some powdered nitre. It is then well washed and digested with strong hydrofluoric acid. It is again heated with sulphuric acid, and the washed residue is repeatedly digested with strong warm nitric acid and chlorate of potash. When the above series of operations has been effectively carried out, the material which remains is fused with fluor-hydrate of fluoride of potassium. The fused mass is then boiled in water, and the insoluble mass is finally heated with sulphuric acid.

The grains which resist this final treatment are found to consist of carbonado, and crystalline carbon or diamond. It is noteworthy that the latter consist of broken fragments, no complete crystals (according to Sir William Crookes) having yet been seen; and it is considered probable that this is due to their having burst on being liberated from the intense pressure under which they were formed. It has already been stated that fractured diamonds are also of very common occurrence in the South African mines. The largest diamond yet produced by Moissan's system was less than one millimetre in diameter.

It was considered that in Moissan's process great pressure was an essential factor in the crystallising of the diamond; nevertheless, since the date of his experiments microscopic diamonds are said to have been found in ordinary cast-iron* which has not been suddenly cooled.

Dr. Friedlander, of Berlin, in 1898, succeeded in producing microscopic diamonds without the aid of pressure, and without employing metallic

* Geol. Mag., 1898, V (4), p. 226.

iron. He was influenced in his reasoning by the fact that no metallic iron was known to be present in the diamantiferous pipes of South Africa. If, therefore, the Kimberley diamonds had been naturally formed by a process analogous to that devised by Moissan, it was necessary to assume that the crystals, after formation in molten iron at a great depth below the surface, had floated into the molten silicate-material above. This supposition was, however, upset by the fact that the diamond-bearing rock, when fused under small pressure, dissolves any diamonds contained in it.

Friedlander then tried the experiment of fusing a small fragment of the mineral *olivine* before a gas blowpipe, keeping the upper portion of it in a molten state for some time, and stirring it with a little rod of graphite. When the olivine had again solidified, it was found to contain a vast number of microscopic crystals, but only in the part which had been in contact with the graphite. These crystals are said to have been octahedral or tetrahedral in form, and to have possessed all the other physical and chemical properties of the diamond.

*Theories in regard to the Genesis of the diamond.*—The discovery, in 1870, of diamonds in volcanic pipes in South Africa appeared to be a distinct advance in the investigation as to the origin of the gem, and several ingenious theories were subsequently advanced by scientific men, whose arguments were based, not only on the composition of the rocks and minerals accompanying the diamond at Kimberley, but on the methods employed by chemists in the production of artificial diamonds. It seemed a reasonable conclusion that carbon could assume a crystalline form only under the influence of great heat and pressure; and in the volcanic pipes of Kimberley both these conditions would be available, their intensity being governed only by depth.

Mr. E. J. Dunn was the first who referred the origin of the Kimberley diamonds to the beds of carbonaceous shale which form the walls of the pipes near the surface. His theory was communicated to the Geological Society of London, in 1881, in a paper entitled, "Notes on the Diamond Fields of South Africa." He drew attention to the occurrence at all the mines of considerable deposits of black carbonaceous shale underlying the surface beds of gray shale. These carbonaceous shales, he stated, were certainly more than one hundred feet thick, though their exact depth had not then been ascertained, and they extended horizontally over the whole of the country in which the pipes are situated. That the mines are volcanic pipes, and that they have burst through these carbonaceous shales he regarded as evident, and he thought it was reasonable to infer that the carbon, which is indispensable, in one form or another, to the formation of the diamond, was supplied by these shales. He stated that the yield of diamonds in these pipes was greatest when mining was carried on in the portions of the pipes surrounded by carbonaceous shales, rendering it probable that these shales supplied the element necessary to the formation of diamond.

This line of reasoning, he considered, led to the important question as to whether diamonds would be found in the pipes below the limits of the carbonaceous shales for the tendency of the material forming the filling of the pipes would have been to raise the diamonds to a higher level than that at which they were formed.

In reference to the last question, it may be stated that exploratory workings have now been carried down to a depth of over 1,800 feet in the Kimberley Mine, and it has been proved that the carbonaceous shales (which belong to what are termed the "Karoo Beds," and are of Mesozoic age) do not extend more than about 350 feet below the surface; nevertheless, diamonds are still found as plentifully in the bottom of the mine as they were in the upper levels. Moreover, in the Reitfontein Mine, near Pretoria, which is the most recently discovered diamantiferous pipe, the carbonaceous shales do not occur at all, the pipe intersecting only Palæozoic rocks. It is, however, possible that sufficient carbon to account for the formation of the diamonds may exist in the older rocks penetrated by all the pipes, and the Magaliesberg quartzites, in which the Reitfontein pipe occurs, are said to contain layers of graphite.

In June, 1897, Sir William Crookes, F.R.S., delivered a lecture on "Diamonds," at the Royal Institution, in London; during his discourse he described and illustrated the artificial manufacture of diamonds by Moissan's method, and in discussing the genesis of the gem in nature, he expressed the opinion that the diamond of the chemist and the diamond of the mine are strangely akin as to origin. He pointed out that the country round Kimberley is remarkable for its ferruginous character, insomuch that iron-saturated soil is popularly regarded there as one of the indications of the near presence of diamonds. He contended that the pipes are not filled with the eruptive rocks, scoriaceous fragments, &c., constituting the ordinary contents of volcanic ducts; also that the appearance of the fragments of shale and other rocks shows that the mélange has suffered no great heat in its present condition, and that it has been erupted from great depths by the agency of water vapour, or some similar gas.

Finally, he advanced the theory that at a sufficient depth below the pipes there were masses of molten iron at great pressure and high temperature, holding carbon in solution ready to crystallise out on cooling; that water then found is way to the molten iron through cracks in the overlying strata, and was immediately converted into gas, which disintegrated and eroded the channels through which it passed, grooving a passage more and more vertical in the effort to find the quickest vent to the surface. The erosion of the pipes was, he thought, also assisted by volumes of hydrogen and hydrocarbons, generated by the action of the water upon the molten iron. Finally, as the violence of the action diminished, the pipes were filled from below with a water-borne magma consisting of rocks, minerals, iron oxide, shale, and petroleum.

Dr. Friedlander, of Berlin (whose experiments have already been alluded to) claims, however, to have shown that diamonds can be prepared by simply fusing a piece of the mineral *olivine*, and stirring the fused mass with a rod of graphite. His contention, therefore, is that the South African diamonds may have been formed in a simpler manner than that suggested by Sir William Crookes, viz., by the action of a molten silicate, such as olivine, on graphite. In support of his theory he refers to the fact that carbonaceous shales are penetrated by the diamond-bearing rock, and also that numerous fragments of the shale, in an altered condition, are found enclosed in the rock itself.

The late Professor H. Carvill Lewis regarded the rock which forms the filling of the Kimberley pipes as originally an extremely basic igneous rock, or lava, now serpentinised, and he proposed the specific name of Kimberlite for it. He considered this rock to be the absolute matrix of the diamond, and that the latter owed its origin to the contact of the lava with the carbonaceous beds.

Professor T. G. Bonney, D.Sc., F.R.S., has for years been one of the most assiduous of European geologists in the effort to elucidate the origin of the diamond in the Kimberley Mines. He described the various minerals associated with the gem, and stated that they are not such as are likely to have been formed *in situ*, but were more probably derived from the destruction of rather coarse peridotites, pyroxenites, and eclogites. He regarded the blue ground as a volcanic breccia, cemented together by secondary minerals. He contended from the first that the diamonds were not formed in this rock *in situ*; but, like the garnets which accompany them, had their origin elsewhere, probably at a distinctly greater depth from the surface. According to his reading of the problem, the crystalline rocks below the Karoo beds are the true matrix of the diamond. Volcanic action commenced before the end of the Karoo Epoch, as shown by the great sheet of melaphyre (? diabase), which appears to be intercalated with the upper beds of the series. Subsequently the pipes were formed by a series of great explosions, caused by gases accumulated at considerable depth. These sent the outer part of the underlying crystalline rocks (including the diamonds), as well as the overlying Karoo shales, flying shattered into the air. Most of the shattered material probably fell back, after a few explosions, into the pipes, and filled them like the volcanic necks of Scotland. Then, after some more lava had reached the surface in the form of dykes, the volcanoes passed into a solfataric state, during which numerous secondary changes were produced, the carbonates were deposited, and the minor structure of the mass was obscured. Afterwards ordinary meteoric agencies began to work; water percolating from above still further affected the mass, more especially in its upper parts, producing the "yellow ground" and the "soft blue," and depositing tufa.*

* *Geol. Mag.*, 1897, IV (4), p. 501.

In June, 1899, Professor Bonney published another paper which appears to confirm in a remarkable manner the correctness of his previous conclusions. It contains a description of some boulders of *eclogite* which were taken from the *blue ground* in one of the Newlands pipes in West Griqualand. This rock is coarsely granular, and is composed of pink garnets (varying in size from a hemp-seed to that of a pea), together with a green-coloured mineral which he identified as chrome-diopside, a variety of pyroxene. The garnets have what is known as a kelyphite rim or crust (about as thick as the thumb-nail) surrounding them. In one specimen of this rock were embedded no less than ten small diamonds, varying in size from ·05 to ·15 inch in length. Professor Bonney was of opinion that the specimens of eclogite were truly water-worn boulders. His final conclusions are contained in the following extract :—

"Thus the diamond has been traced up to an igneous rock. The '*blue ground*' is not the birthplace either of it or the garnets, pyroxenes, olivine, and other minerals, more or less fragmental, which it incorporates. The diamond is a constituent of the eclogite, just as much as a zircon may be a constituent of a granite or a syenite. Its regular form suggests not only that it was the first mineral to crystallise in the magma, but also a further possibility. Though the occurrence of diamonds in rocks with a high percentage of silica (itacolumite, granite, etc.) has been asserted, the statement needs corroboration. This form of crystallised carbon hitherto has been found only in meteoric iron, and has been produced artificially by Moissan and others with the same metal as matrix. But in eclogite the silica percentage is at least as high as in dolerite ; hence it is difficult to understand how so small an amount of carbon escaped oxidation. I had always expected that a peridotite (as supposed by Professor Lewis), if not a material yet more basic, would prove to be the birthplace of the diamond. Can it possibly be a derivative mineral, even in the eclogite ? Had it already crystallised out of a more basic magma, which, however, was still molten, when one more acid was injected, and the mixture became such as to form eclogite ? But I content myself with indicating a difficulty, and suggesting a possibility ; the fact itself is indisputable ; that the diamond occurs, though rather sporadically, as a constituent of an eclogite, which rock according to the ordinary rules of inference, must be regarded as its birthplace."

"This discovery closes another controversy, viz., that concerning the nature of the '*hard blue*' of the miners (Kimberlite of Professor Lewis), in which the diamond is usually found. The boulders (of eclogite) described in this paper are truly water-worn. The idea that they have been rounded by a sort of 'cup-and-ball' game played by a volcano may be dismissed as practically impossible. Any such process would take a long time, but the absence of true scoria implies that the explosive phase was a brief one. They resemble stones which have travelled for several miles down a mountain torrent, and must have been derived from a coarse conglomerate, manufactured by either a strong stream or the waves of a sea from fragments obtained from more ancient crystalline rocks." . . . . .

"Thus the presence of waterworn fragments, large and small, in considerable abundance, shows the '*blue ground*' to be a true breccia, produced by the destruction of various rocks (some of them crystalline, others sedimentary, but occasionally including water-worn boulders of the former)—*i.e.*, a result of shattering explosions, followed by solfataric action. Hence the name *Kimberlite* must disappear from the list of the peridotites, and even from petrological literature, unless it be retained for this remarkable type of breccia."

"Boulders, such as we have described, might be expected to occur at the base of the sedimentary series, in proximity to a crystalline floor. The Karoo beds in South Africa, as is well known, are underlain in many places by a coarse conglomerate of considerable thickness and great extent, called the Dwyka Conglomerate, which is supposed to be Permian or Permo Carboniferous in age. It crops out beneath the Karoo beds at no great distance from the diamond-bearing district, and very probably extends beneath it. If this deposit has supplied the boulders, the date of the genesis of the diamond is carried back, at the very least, to Palæozoic ages, and possibly to a still earlier era in the earth's history."*

*The occurrence of Diamonds in New South Wales.*—Diamonds are widely distributed in this country, as will be understood by referring to the appended list of localities ; nevertheless, it cannot be said that the diamond-mining industry has yet been established on a very firm basis, and, indeed, mining operations in search of the gem have only been carried on in a limited number of places. The discovery of diamonds, in nearly every instance, has been made by miners engaged in the washing of alluvial gravels for gold.

The first definite record of the finding of diamond is contained in a letter from the late Mr. E. H. Hargraves to the Colonial Secretary, and was published as a parliamentary paper. The letter was dated Guyong, 2nd July, 1851, and the following is an extract from it :—"A sample of the gold from this locality is herewith enclosed, together with some stones (not very precious) ; a small one of the diamond kind you will perceive, which cuts glass as well as any glazier's diamond I ever saw."

In an official report, dated 18th October, 1851, the late Mr. S Stutchbury, Geological Surveyor, stated that he had seen "a small but beautifully-crystallised diamond from the Turon River."

In 1860 the late Rev. W. B. Clarke published a description of six diamonds which he had tested. Four of these were obtained in the bed of the Macquarie River, near Suttor's Bar, the fifth was from the mouth of Pyramul Creek, and the sixth was from Calula Creek. The largest of these stones weighed 2·446 carats.

* *Procs. Roy. Soc.*, LXV, No. 417, pp. 235–236.

In 1867 diamonds were discovered in some quantity in auriferous gravels at a locality known as Two-mile Flat, on the Cudgegong River, about nineteen miles north-west of Mudgee. Two years later several companies started to systematically work the deposits; but, although a large number of diamonds was obtained, the industry did not prove profitable, owing to the small average size of the stones, the expense of sinking through hard basalt, and the cost of carriage of the wash-dirt to water. Finally, most of the machinery was destroyed by the disastrous flood of 1870.

*The Cudgegong Diamond Field.*—The Cudgegong deposits were described in much detail by Professor Thompson and Mr. Norman Taylor,* who showed that they consisted of a number of isolated patches of an older river drift, situated at an elevation of about forty feet above the present bed of the Cudgegong River. The older drift is overlaid by basalt, and is probably of Pliocene age. Denudation during Post-Pliocene times has removed much of the basalt and drift, leaving isolated areas at the following localities:—Jordan's Hill, 40 acres; Two-mile Flat, 70 acres; Rocky Ridge, 40 acres; Horseshoe Bend, 20 acres; Hassall's Hill, 340 acres—total, 510 acres.

The gravels varied from a few inches up to seventy feet in thickness, and contained boulders and pebbles of hard slate, sandstone, quartz, greenstone, felstone, quartzite, and jasper, with cement and sand. With the diamonds were associated the following metals and minerals, viz.:—Gold, osmiridium, wood-tin, titanic acid (? Brookite), magnetite, ilmenite, tourmaline, garnet, pleonaste, topaz, zircon, sapphire, adamantine-spar, barklyite, ruby, and quartz.

The diamonds were distributed sparingly through the drift, and were not confined to any particular level. The largest gem discovered on the field was a colourless octahedron weighing $5\frac{5}{8}$ carats; another, weighing $3\frac{1}{4}$ carats, was also found. During the first five months of systematic washing over 2,500 diamonds were discovered, and several thousand more were afterwards obtained. The gems were mostly colourless, but many had a straw-yellow tint, and tints of brown, light or dark bottle-green, and black were more rarely met with. One or two opaque black ones (carbonado) were found, and another of a dark-green colour with the external appearance of having been polished with black lead. Black specks within the crystals were not uncommon. The average specific gravity was found to be 3·44. As regards the average size of the stones, the following particulars of a parcel were given:—

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 106 | diamonds | weighed | $74\frac{1}{2}$ | carats, | the largest | $1\frac{3}{5}$ | carats. |
| 81 | ,, | ,, | 19 | ,, | ,, | $1\frac{1}{2}$ | ,, |
| 110 | ,, | ,, | $26\frac{1}{2}$ | ,, | | | |
| 16 | ,, | ,, | 6 | ,, | | | |
| 700 | ,, | ,, | $151\frac{1}{3}$ | ,, | | | |

The average weight of the diamonds, therefore, was 0·224 carat

* *Trans. Roy. Soc. N. S. Wales for* 1870, pp. 94–106

*The Bingara Diamond Field.*—Shortly after the discovery of the Cudgegong mines, diamonds were found in very similar deposits near Bingara, in the County of Murchison. About five miles west-south west of the township of Bingara is a considerable area of water-worn gravels, capping the foot hills of a high basalt-covered range. In the range itself there are two distinct flows of basalt, the upper of which is about 350 feet in maximum thickness; it overlies about 120 feet of fluviatile sands and gravels (probably of Pliocene age), which are said to contain some diamonds, though this requires corroborating. Below these alluvials is an older sheet of basalt, about 300 feet thick, resting upon sands, clays, and ironstones, which have a total thickness of about 400 feet, and which are probably of Miocene age. These older alluvial beds are not known to contain diamonds.

The isolated patches of diamantiferous gravels which cap the foot-hills are probably the remnants of a portion of the newer (Pliocene) river drift, which has been largely removed by denudation.

The foot-hills extend down to the Gwydir River, and along the banks of the latter are considerable deposits of water-worn gravels, which have evidently been redistributed in post-Pliocene times; it is said that occasional diamonds have been found in this loose material.

The area of the proved diamantiferous ground (not including the basalt range, the drifts in which have not been worked) has been estimated at about 200 acres. The wash has a maximum thickness of about sixty feet, but those portions of it which have been proved to be diamond-bearing vary from a few inches up to eight or nine feet in thickness.

The underlying rocks consist of indurated claystones, sandstones, quartzites, conglomerates, and limestones, with interbedded marine tuffs. This sedimentary series is of Carboniferous age, the most characteristic fossil found in the claystones being *Lepidodendron australe* (McCoy). Intrusive dykes of diorite and felspar porphyry are not uncommon, while to the east and south of Bingara the Carboniferous rocks have been intruded by a tourmaline granite massif, and an extensive serpentine dyke is also a noticeable feature.

The pebbles composing the diamantiferous wash vary in size from that of a pea up to two feet in diameter; most of them are well-rounded, though there are also some angular and sub-angular fragments. They consist of claystone, jasper, lydian stone, quartz, felspar porphyry, &c. Professor Liversidge, in 1873, determined the various metals and minerals associated with the diamond at Bingara, and enumerated the following, viz.:—tourmaline, zircon, sapphire, topaz, garnet, spinelle, quartz, brookite, ilmenite, magnetite, wood-tin, gold, and osmiridium.

The diamonds are, as a rule, of small size, averaging about five to the carat. The largest stone found on the field is said to have weighed $2\frac{5}{8}$ carats. More than fifty per cent. of the diamonds are straw-coloured. The wash has proved to be very variable in richness; thus in one instance fifteen loads are said to have yielded 2,189 diamonds, while in other cases yields of less than one-quarter carat per load have been obtained.

During the years 1872–3 rather an extensive rush for mineral leases occurred in this locality, and it was then anticipated that the diamond-mining industry would become a permanently payable one. However, the stones found were mostly small, and, the Sydney jewellers declining to purchase, there was no outlet, and work was suddenly abandoned. Several efforts have since been made to work these mines, but the results have not, apparently, been very remunerative. The richest claim, known as the Monte Cristo, is understood to have been purchased recently by the Inverell Diamond Fields (Limited) and it was currently reported that the purchase money amounted to £5,000, but at the present time the mine is not being actively worked.

There is no complete record of the number of diamonds obtained from the Bingara Field since its discovery, but in the year 1887 it was estimated that at least 12,000 diamonds had up to that time been recovered.

*The Cope's Creek or Boggy Camp Diamond Field.*—After the discovery of the alluvial tin deposits of the Inverell District, diamonds were found from time to time by the miners who were working the stanniferous gravels in the bed and along the banks of Cope's Creek, from Tingha down to the junction of the Gwydir River, but it was not until some years later that the diamonds were traced to an older formation, similar to those which have already been described as containing diamonds at Bingara and Cudgegong.

Cope's Creek junctions with the Gwydir, in the Parish of Mayo, County of Hardinge, about fifteen miles south-west of Inverell, and close to the recently built town of Boggy Camp. The geological formation of this country consists of indurated claystones and tuffs, of Carboniferous age, and coarse porphyritic granite which has intruded the sediments. In the neighbourhood of Boggy Camp there is a number of isolated basalt-capped hills, and beneath the basalt are deposits of sands and gravels (probably of Pliocene age) containing diamonds, stream-tin, and a little gold. These hills have been given distinctive names, such as Collas Hill, Red Hill, Round Mount, Boggy Camp, Soldier's Hill, Malacca, Stockyard Hill, &c. They are portions of what was once a continuous basalt-capped *lead*, which followed approximately the present course of the Gwydir River, but the intervening portions have been removed by denudation, which has also deepened the existing river valley, leaving these isolated and elevated patches of gravel protected by their covering of basalt.

There has been more systematic mining for diamonds on this field than on any other in New South Wales. The late Mr. C. S. Wilkinson, Geological Surveyor in Charge, reported that, in 1886, 23,000 diamonds, weighing 5,151 carats, were obtained in the neighbourhood. More recently a number of claims were amalgamated, and two English companies started mining operations on an extensive scale.

The gravels in which the diamonds are found consist of waterworn pebbles and boulders of claystone, sandstone, quartz, and granite; some of the last-named are as much as ten feet in diameter, but they are usually decomposed. The wash also contains a considerable amount of sand derived from the disintegration of granite. The minerals associated with the diamonds are identical with those found at Bingara, but there is usually a greater proportion of tin and a smaller amount of gold present; thin waterworn prisms of tourmaline (called *pencils* by the miners) are also very numerous. The diamonds are of a distinctly larger size than those found at Cudgegong or Bingara, the average being about three to the carat.

The Inverell Diamond Fields (Limited) hold an area of 400 acres under lease, including the Round Mount and the greater part of the basalt hill adjoining Boggy Camp township. Some exceedingly rich prospects were obtained from some of this land before it was acquired by the Company. Thus in 1895 the prospectors obtained from one load of wash no less than 515 diamonds, weighing in the aggregate 184 carats, and forty-two loads of wash yielded 600 carats of diamonds and 546 ℔. of stream tin.

When the mines passed into the hands of the Company, a diamond-washing plant, capable of treating 250 loads per week, was erected, and during the year 1898 between 1,200 and 1,300 loads of gravel were washed for a total yield of 12,196 carats of diamonds; the gravel also returned at the rate of about fifteen pounds of stream tin per load, which nearly paid for the cost of treatment. Nearly the whole of this material was taken from exploratory drives and cross-cuts, the total length of which amounted to about 5,000 feet.

The publication of these returns created great excitement in the district, and the shares of the Company soon rose to a high premium. The old washing plant was pulled down, and a new one, capable of dealing with 300 loads of gravel per day of eight hours, was erected in its place. A 6-inch pipe-line was laid to the river, a distance of 7,400 feet, and water was pumped to a service reservoir, whence it gravitates to the works. Mining operations were then renewed on a larger scale, and, as a consequence of the increased expenditure, the township of Boggy Camp sprang into existence in a remarkably short space of time.

The output for 1899 was 21,830 carats of diamonds, and 20 tons 18 cwt. of stream tin. The gravel is understood to have subsequently become much poorer, and in 1900 the Company obtained suspension of labour conditions, and the mines were temporarily closed. The total output of the Inverell Diamond Fields (Limited), from July, 1897, to the cessation of work in 1900, was 37,400 carats of diamonds and thirty-nine tons of stream tin.

The largest stone hitherto found in these mines weighed six and a quarter carats, and this is also believed to be the largest diamond found in New South Wales of which there is any authentic record. It was what is termed an "off-colour fracture," *i.e.*, a straw-coloured broken fragment of a crystal, and from its appearance it was estimated that the original stone may have weighed about fifteen carats. About half a dozen three-carat stones were also found in the course of a year, but the average size of the gems was one-third of a carat.

The average thickness of gravel in these mines is from three to four feet, and its maximum thickness, so far as known, is fourteen feet. It is evident that the diamonds are not evenly distributed through the wash, but that they have been more or less concentrated in patches.

The accompanying photograph shows the arrangements of the large washing plant erected by the Inverell Diamond Fields.

The gravel is brought from the mine tunnel in trucks, and is tipped into a shoot, through which it is delivered into a revolving cylindrical screen or trommel, of $\frac{3}{4}$-inch mesh. The material, as it enters the trommel, meets a spray of water; the heavy stones pass down through the cylinder into a truck which conveys them to the dump. The finer material, which passes through the $\frac{3}{4}$-inch screen, is conveyed through launders into the first of two circular pans or puddling machines, fourteen feet in diameter, and fitted with eight horizontal arms, which revolve round a central axis. Each arm is furnished with seven tines or knives, fixed vertically, with their blades arranged spirally in such a manner that their revolution tends to move the heavy material to the circumference of the pan.

The overflow from the first pan is through a vertical cylinder in the centre, and passes into the second pan. The diamonds are nearly all retained by the first pan; it is cleaned up every day, whereas the second pan is cleaned up only once a week.

The pans are always worked with muddy water, which is brought back for this purpose from the tailings elevator. It is found that, if clean water be used in the pans, the material has a tendency to set therein like cement, and more power is required to work the puddles than is the case when muddy water is used; moreover, the fine sand escapes in the overflow more readily in muddy than in clear water.

When the pans are cleaned up the washed material is pushed through a trap-door in the bottom into a tank, and is thence elevated to a revolving cylindrical screen or trommel, where it meets a spray of water. The wire screens of this trommel are of four distinct meshes, arranged in zones, the finest mesh (twelve holes to the inch) being at the top end. The coarse material gravitates down through the interior of the trommel and falls on a table, where it is examined for large diamonds and then conveyed to the dump. The finer material is graded by the screens of

*Photographed by E. F. Pittman*

DIAMOND-WASHING PLANT.—THE INVERELL DIAMOND FIELDS, LIMITED, BOGGY CAMP, NEAR INVERELL.

the trommel, and passes direct to the four compartments of a pulsator or jigger of the type used at Kimberley. The screens of this pulsator are covered with a layer of shot of different sizes to suit the mesh of the screens, and the diamonds, and other minerals of high specific gravity pass through the shot as the latter are separated by the pulsations imparted to the water, and fall into the hutches or compartments below. There are four compartments, viz., one large, two medium, and one small.

The diamonds pass from the hutches by pipes which deliver them on to circular hand sieves placed on a table. The sieves when full are immersed in a tub of water, and are carefully shaken so as to allow the heavier minerals to settle at the bottom. They are then suddenly inverted on the table, and the diamonds, which are found on the top of the heap, are picked out with a pair of pincers.

The capacity of the plant is 300 cubic yards of gravel per eight hours. The engine is of 18 horse-power, and the boiler 25 horse-power.

*The Australian Diamond Fields (Limited)* hold a considerable area to the south, but work has recently been suspended here also.

*The Elliott Diamond and Tin-mining Co.*, have just started mining operations on some land adjoining the Inverell Diamond Fields on the east. The first washing is understood to have yielded at the rate of between three and four carats of diamonds and over forty pounds of stream tin per load. Other mines in the neighbourhood of Boggy Camp are being worked on a smaller scale.

*Ryder Brothers Diamond Mine.*—About five miles south of Boggy Camp, in the Parish of Astor, County of Hardinge, a diamantiferous lead has been worked by Ryder Brothers; it is situated on Long Arm Gully, a tributary of Maid's Creek. The country is granite, and the diamantiferous gravel is about two feet thick, while the depth of sinking is about sixty feet. The gravel is very similar in character to that of the Boggy Camp Mines; near the bottom of it there is a band, about an inch thick, of hard ferruginous cement, and in several instances diamonds have been found imbedded in this. The average size of the stones in this mine is distinctly larger than in those around Boggy Camp; in 1898 one irregularly-shaped diamond weighing three and a half carats was obtained, and twelve stones, each of which exceeded two carats in weight, were also won. A small circular hill of basalt covers the lead at its lower end near the creek, and several shafts sunk around its circumference appear to show that the gravels dip towards the centre of the hill from all sides; the shafts were, however, unable to bottom owing to the strong body of water met with. A granite bar has been proved to cross the lead between the hill and the creek, so that it appears as if the basalt has filled a deep pool in the bed of the old drainage channel, and there is a probability that good stones may be found in this depression.

### Diamonds in Volcanic Breccia.

*The Ruby Hill Mine.*—The diamantiferous deposits hitherto considered are all of a detrital character, and although it has been contended by some geologists that the diamonds may have been actually formed in the alluvial drifts where they are found, it is far more probable that they have been deposited there by the action of running water, and that we must seek for their true matrix in some older formation.

The discovery that the diamonds of the river gravels of South Africa had been derived from the disintegration of a breccia, occurring in volcanic pipes, induced the hope that those of the Australian gravels might be traced to a similar origin, more especially as there are many points of resemblance in the geology of the two countries.

Quite recently diamonds have been found in New South Wales, under conditions which appear to be analogous to those of the Kimberley mines, for although the excavations hitherto made are insufficient to place the matter beyond all doubt, the surface indications certainly seem to show that diamonds occur in a volcanic breccia, similar in its character and mode of occurrence to that of Kimberley.

The site of this interesting discovery is known as Ruby Hill, and is situated in the Parish of Dinoga, County of Murchison, about twelve miles south of Bingara, and close to the Barraba road.

A small hill, about eighty feet in height, which is intersected by several basalt dykes, was pegged out some years ago by a miner named Butt, who was attracted by some red crystals in the basalt. Under the impression that these crystals were rubies, Butt drove a tunnel, forty feet in length, in one of the hard basalt dykes, and only desisted on being informed that the red stones were garnets, and of no value. Subsequently the land was taken up as a mineral lease by one Leonard Court, and he brought it under the notice of Messrs. Pasley, Gordon, and Morkel, officers on the staff of the Inverell Diamond Fields (Limited). Mr. Morkel is a native of South Africa, and on inspecting the hill, in December, 1889, he stated that, in his opinion, it was a volcanic pipe similar to those of Kimberley, with which he was familiar. Messrs. Pasley, Gordon, Morkel, and Court thereupon formed a small syndicate for the purpose of testing the ground, and they put down a shaft on the flat at the foot of the Hill. This shaft penetrated creek gravel for a depth of twenty-three feet, but below that a breccia was met with, which Morkel declared was *yellow ground.* The shaft was continued in this material for fifteen feet, when work had to be temporarily abandoned owing to the occurrence of a strong body of water. The breccia taken out of the shaft was washed in a tub with hand-sieves, and ten diamonds, weighing in the aggregate four and one-eighth carats, were obtained from it.* The diamonds were remarkable in that they each had a distinct depression or pitting on one of the faces.

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* Mr. Pasley states that there is no doubt whatever that these diamonds were obtained in the *volcanic breccia* and not in the *creek gravel.*

*Photographed by E. F. Pittman.*

RUBY HILL, NEAR BINGARA.

Composed of Volcanic Breccia, said to contain Diamonds.

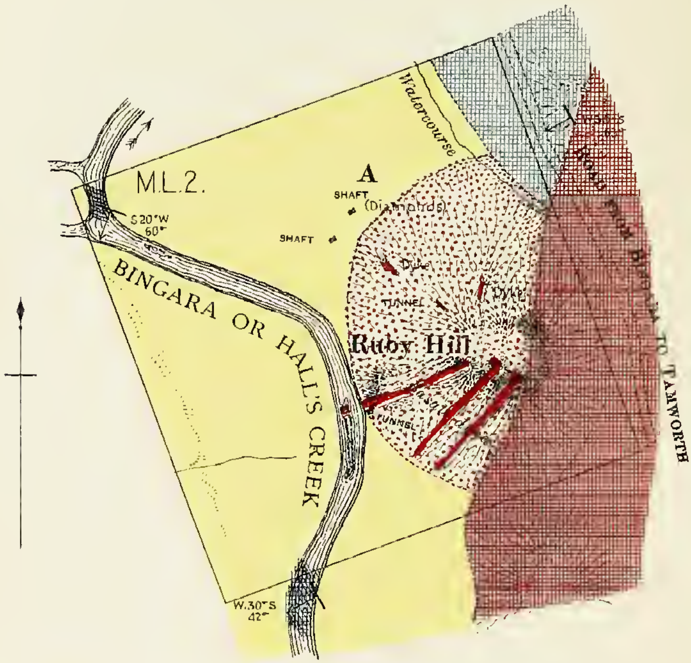
## PLAN OF DIAMANTIFEROUS VOLCANIC PIPE

PARISH OF DINOGA, COUNTY OF MURCHISON.

Geologically Surveyed by E. F. Pittman, A.R.S.M., Government Geologist

Assisted by O. Trickett, L.S.

Scale 0 5 10 Chains




REFERENCE

**Pleistocene**

*Alluvium (Gravel and Soil)*

**Tertiary (?)**

*Volcanic breccia or agglomerate, covered by loose boulders of basalt. (The breccia consists of angular and sub-angular fragments of claystone, felsite, basalt, eclogite, etc., with calcite, garnet, zircon, chrome diopside, etc.)*

*Dykes of Basalt (containing garnets and inclusions of eclogite)*

**Post-Carboniferous**

*Intrusive quartz felsite*

**Carboniferous**

*Banded claystones and tuffs.*

62326

*Photo-lithographed by W. A. Gullick, Government Printer,*

Notwithstanding the apparent confirmation of his opinion, by the finding of these gems, Morkel thought so little of the deposit that he abandoned his share and shortly afterwards returned to South Africa. Messrs. Pasley and Gordon, however, determined to further prospect the breccia, and in September, 1900, they applied for aid from the Prospecting Vote to continue the shaft.

An examination of the hill was then made, and the indications were considered so interesting that a grant of aid was recommended to put in a tunnel, about half way up the hill, as a preliminary to sinking a shaft from the top.

The accompanying plan shows the geological formation of the surface of the hill and of the country in its immediate vicinity. The sedimentary rocks of the neighbourhood are the typical banded claystones and tuffs of the Carboniferous era, which cover a large portion of the country between Tamworth and the Queensland border. Small patches of these rocks outcrop near the north-east, north-west, and south-west corners of the mineral lease, but over a considerable portion of the intervening area they have been covered by alluvial gravel and soil, deposited by the flood waters of Hall's Creek during Post-Tertiary times. The carboniferous sediments have been intruded (probably during Permian or early Mesozoic times) by a mass of micro-crystalline quartz-felsite, and the original line of junction between the igneous and the sedimentary rocks passes across Ruby Hill very near its centre. The intrusive character of the quartz-felsite is well seen in the bank of Hall's Creek, about one-third of a mile to the south of the hill, where its actual contact with the sedimentary series is exposed.

The eastern side of Ruby Hill, therefore consists of quartz-felsite, which in fact extends to its summit; but that portion of the hill facing the north, west, and south is composed of a volcanic breccia, identical with that obtained in the shaft (the position of which is shown on the plan by the letter A), from which the diamonds were obtained. The hill is intersected by five basalt dykes, and its slopes are also loosely covered by small boulders of basalt, but between and beneath these the breccia can be easily distinguished.

It would appear, therefore, that this is an undoubted point of eruption—that the hill is, in fact, the denuded remnant of a volcanic pipe which was formed (during the Tertiary times) at a position of former weakness, viz., on the actual junction of the old intrusive quartz-felsite with the Carboniferous sediments.

The breccia bears a very striking resemblance to the volcanic agglomerate of the Kimberley pipes, the principal difference being that it shows no sign of serpentinisation. It has been decomposed to a depth of only a few feet, and in its undecomposed state it is of a dark greenish-blue colour. It is made up chiefly of angular fragments and masses (though there are also occasional rounded pebbles) of other rocks, such as claystone, amygdaloidal basalt, quartz-felsite, eclogite, &c., with garnets, chrome-diopside, magnetite, zircons, and a considerable quantity of secondary calcite. The rock fragments making up the breccia have in many cases an altered or bleached appearance, such as would be produced by heat, but their edges do not appear to have been fused. A complete determination of all the rock and mineral constituents of the breccia is being made by Mr. G. W. Card, A.R.S.M.

Perhaps the most interesting feature in connection with this formation is the occurrence, on the slopes of the hill, and also in the breccia taken from the shaft, of irregular-shaped pieces of coarsely crystalline rock, made up of garnets, felspars, and crystals of a bottle-green coloured mineral. In some cases the garnets have a very distinctly marked crust (probably what is known as a kelyphite rim) enveloping them. Considerable quantities of this rock have been met with in the undecomposed breccia extracted from the tunnel which has recently been started. It is also of fairly frequent occurrence in the dense basalt of the dykes, forming irregular-shaped inclusions several inches in diameter. Thin slices of this rock have been carefully examined by Mr. G. W. Card, Curator and Mineralogist, of this Department, and Mr. W. G. Woolnough, Demonstrator of Geology at the Sydney University, and it has been determined by them to be an *eclogite*, consisting of a crystalline granular mixture of garnet, anorthite, or a felspar allied thereto, and the variety of pyroxene known as chrome diopside.

This rock, from the same locality, has been previously described by the Rev. J. M. Curran, as "a holocrystalline granular basic rock, composed of pyroxene, felspar, and kelyphite rings of a composite substance surrounding garnet." He regarded the hill as an isolated hummock of basalt, and the garnet rock as a segregation from the basalt.*

As already stated, Professor Bonney, F.R.S., has announced that an eclogite is, if not the parent, at least the foster-parent rock of the diamond in South Africa. He has described rounded boulders of this rock from the *blue ground* of the Newland's pipe, one of them containing no less than ten small diamonds embedded in it; and he has stated that in his opinion the boulders are *waterworn*, and have been derived from a bed of conglomerate through which the volcanic eruption has passed.† This is equivalent to saying that the occurrence of the diamonds in the Kimberley pipes is more or less an accident, depending upon the presence of a particular stratified rock in the path of the volcanic outburst.

Is it then to be regarded as nothing more than a mere coincidence that here, in Australia, we find diamonds associated with the same rock (eclogite), and under precisely similar conditions, viz., in an agglomerate filling a volcanic vent? And is it to be concluded that the Ruby Hill pipe has also burst through a deep-seated bed of conglomerate formed of waterworn pebbles of eclogite? The fragments of eclogite in this case have not yet been found in the form of waterworn pebbles;

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* *Journ. Roy. Soc. N. S. Wales*, 1896, XXX, p. 248.

† *Procs. Roy. Soc.*, 1899, LXV, No. 417, pp. 235, 236.

but a small proportion of the other rock fragments composing the breccia have a rounded appearance, and this is not by any means an uncommon occurrence in volcanic agglomerates. Is it not more probable, however, that the rounded pebbles really owe their form to attrition, the result of contact with other ejectamenta during repeated ascent and descent in the vent?

The coarsely crystalline character of eclogite is evidence in favour of the rock having been formed at great depth, and in view of the occurrence of fragments of this rock in volcanic agglomerate in two localities so widely separated from one another as Bingara, in New South Wales, and Kimberley in South Africa, it is difficult to believe that the association is merely accidental; it seems, moreover, to be a rational conclusion that the eclogite is the deep-seated representative of the eruptives which found their way to the surfaces in volcanic pipes at both these places. If this be the case, the formation of the diamond probably occurred in early Tertiary times.

It has yet to be proved whether the Ruby Hill agglomerate contains diamonds in payable quantities; it may be that it does not, but the occurrence of one such deposit renders it extremely probable that others may exist, and that the presence of diamonds in the basalt-covered gravels of Boggy Camp, Bingara, and Cudgegong, is due to the denudation of these volcanic pipes, and the redistribution of their contents in the drainage channels of the Pliocene age.

*The Mittagong Diamond Mine.*—The late Mr. C. S. Wilkinson, Geological Surveyor in Charge, reported in 1890 on the occurrence of diamonds in connection with a supposed volcanic pipe. The following is an extract from his report:—"The diamond mine, so called, is situated about seven miles south-easterly from Mittagong, on a creek flowing into the Nepean River. Here there is a small isolated patch, about 300 feet in diameter, of fine and coarse pebble drift, the remnant of the bed of a stream which, in the Tertiary period, flowed across the Hawkesbury Sandstone formation. It was probably the old channel of the Nepean River before it had been diverted and eroded to form the present valley. The drift rests upon a stiff clay, which forms the surface of a pipe-dyke mass of volcanic breccia, intruding the Hawkesbury formation. For several years it has been, more or less, worked for gold, when, during the process of washing, diamonds were discovered. It is said that they were obtained chiefly from the stiff clay at the bottom of the drift. Mr. Southey who, with Mr. Dunstan, holds the ground, informed me that thirty-three diamonds had been found, the largest weighing $2\frac{3}{4}$ carats. I saw some of these diamonds, which were chiefly well formed octahedra of the first water, the others being a pale yellow colour. If systematic search were made here doubtless many more would be found. Whether the diamonds have been transported with the old Tertiary drift from some formation higher up the Nepean Valley, or have been derived from the volcanic breccia on which the drift rests, or from the Hawkesbury sandstones and shales where they have been altered by contact with the intrusive volcanic rock, has not been definitely ascertained; but it is probable that the breccia is their source. The breccia contains small fragments of coal, and in some respects resembles the diamondiferous rock of the Kimberley field in Africa."

It may be mentioned that since Mr. Wilkinson's report was written an attempt was made to prospect the breccia by means of a shaft. After sinking for about sixty feet, however, a strong body of water was met with, and the mine was abandoned.

*List of localtties where Diamonds have been found.*

NORTHERN LOCALITIES.

| | |
|---|---|
| Ballina. | |
| Bingara District ... ... | Mount Derra-Derra, Doctor's Creek, Eaglehawk Creek, Four-mile Creek, Lady's Gully, Gwydir River, Ruby Hill. |
| Bullawa. | |
| Eulah Creek. | |
| Gragin Creek. | |
| Inverell District ... ... | Boggy Camp, Collas Hill, Round Mount, Malacca, Stockyard Hill, Soldier's Hill, Auburn Vale, Cope's Creek, Middle Creek, Staggy Creek, Tiengah Creek, Gwydir River, Long Arm Gully (Maid's Creek), Tingha, Kimberley, Newstead, Stannifer. |
| Uralla. | |
| Vegetable Creek ... ... | Ruby Tin-mine. |
| Watson's Creek. | |

CENTRAL LOCALITIES.

| | |
|---|---|
| Bathurst District ... ... | Mulgunnia Creek, Campbell River, Trunkey Creek, Caloola Creek. |
| Lachlan River. | |
| Mudgee District ... ... | Macquarie River (Calabash, Suttor's Bar, Katella), Cudgegong River (Horseshoe Bend, Reedy Creek, Two-mile Flat, Hassall's Hill, Jordan's Hill, Rocky Ridge, Cooyal), Narrangarie Range and River, Pyramul Creek. |
| Tambaroora and Turon ... | Bald Hill (Hill End), Monkey Hill, Sally's Flat, Burrandong Creek, Muckerwa Creek, Turon River. |

SOUTHERN LOCALITIES.

Berrima District.
Brooks' Creek, near Bywong.
Burradoo ?
Digger's Creek, Kangaloon.
Doudle's Folly Creek.
Kangaloon, 7 miles from Mittagong.
Shoalhaven River.
Upper Tarlo Creek.
Wingecarribee River.

WESTERN LOCALITY.

Euriowie.

*Production of Diamonds*

The following table, compiled from such information as is available, can only be regarded as an approximation, and is believed to considerably understate the actual output :—

| Year. | Diamonds. | Carats. | Value. £ s. d. |
|---|---|---|---|
| *1867–85 ... ... ... | 12,000 | 2,856 | 2,952 0 0 |
| 1886 ... ... ... | 23,000 | 5,151 | 5,151 0 0 |
| 1887 ... ... ... | 205 | 42† | 26 5 0 |
| 1888** ... ... ... | ......... | ......... | ............ |
| 1889 ... ... ... | ......... | 2,195⅝‡ | 878 5 0 |
| 1890 ... ... ... | ......... | 731½ | 335 0 0 |
| 1891 ... ... ... | ......... | 1,200 | 1,050 0 0 |
| 1892 ... ... ... | 2,285 | 457½§ | 469 0 0 |
| 1893 ... ... ... | ......... | 15,000‖ | 15,375 0 0 |
| 1894 ... ... ... | ......... | 1,772¼‖ | 858 13 6 |
| 1895 ... ... ... | 4,100 | 1,313¶ | 492 7 0 |
| 1896 ... ... | ......... | 8,000 | 2,625 0 0 |
| 1897 ... ... ... | ......... | 9,189 | 3,250 0 0 |
| 1898 ... ... ... | ......... | 16,493 | 6,059 13 6 |
| 1899 ... ... ... | ......... | 25,874 | 10,349 12 0 |
| Totals ... ... | ......... | 90,274⅞ | 49,871 16 0 |

* Estimated. † Result only of 19½ loads washed in January (Cope's Creek). ‡ Output of Malacca Co. (Inverell) only. § From "Monte Christo" Mine (Bingera) alone. ‖ Output from Bingera only. ¶ From Boggy Camp (Tingha) only. ** No information obtainable.

# OPAL.

Opal consists of hydrous silica, the proportion of water varying from 2 to 13 per cent. in different varieties. The mineral is softer than quartz, the hardness of quartz being 7, while that of opal varies from 5·5 to 6·5. Its specific gravity ranges from 1·9 to 2·3. It differs also from quartz in not crystallising in any definite form. Its lustre is vitreous, often inclining to resinous, and sometimes to pearly. In colour it is white, yellow red, brown, green, gray, and blue. It is transparent to opaque. It sometimes presents a brilliant play of colours, and is then called precious or noble opal. Other varieties are known as common opal, milk opal, wood opal, fire opal, etc.

The cause of the play of colour in precious opal is a question which has given rise to some controversy, though there appears to be no doubt that the phenomenon is due to physical structure rather than to chemical composition. According to Brewster it is caused by the presence of microscopic cavities in the stone. Behrends, however, who devoted much time to the investigation of the subject, has shown that this explanation is incorrect. He contends that the play of colours is due to thin curved scales or lamellæ of opal, whose power of refracting light differs slightly from that of the mass; that the lamellæ were originally formed parallel, but have been bent, contracted, and broken during the solidification of the opal.

Common opal occurs in many parts of the Colony, and particularly in the neighbourhood of Orange; it is not, however, of any value.

*Precious* or *noble opal* has been found in two geological formations in New South Wales, viz., in vesicular basalt, and in sedimentary rocks of Upper Cretaceous age; the former has not been worked commercially, but the latter have yielded gems in some quantity and of considerable value.

The first discovery was made on the western side of *Rocky Bridge Creek*, and above the junction of that creek with the Abercrombie River. The deposit was examined, in 1877, by the late Mr. C. S. Wilkinson, from whose report the following extract is taken:—"The matrix of the opal is a horizontal layer, thirty feet thick, of soft decomposed vesicular basalt, which forms part of an old lava stream which flowed down and partly filled up the valley of this creek in the Pliocene period, and it is probable that under this basalt is the bed of the ancient water course containing gold deposits. The numerous vesicular cavities in the basalt are, in some instances, only half filled, and in others completely filled with precious opal, and common opal and hyalite, which have been formed by infiltration of siliceous waters from the rock mass. The precious variety is semi-transparent, and displays fine colours of green, blue, and red shades; but specimens of a size suitable for jewellery purposes can rarely be obtained, so that though this opal rock is of unlimited extent, I doubt much if it would, at the present high price of labour, pay to search for opals. The basalt crops out on the side of a steep range, and could easily be broken out in large masses. The surrounding country is of Silurian formation, traversed by quartz reefs, some of which must be auriferous, as the alluvial deposits in the creek are now profitably worked for gold. A few miles to the north granite occurs, and appears to extend in the direction of Carcoar."*

As little or no work has ever been done on these deposits, they seem to be worthy of the attention of prospectors, as it is possible that valuable stones may be found in the rock if it be properly opened up.

The most important discoveries of precious opal, however, were made at *White Cliffs*, in the County of Yungnulgra, about sixty-five miles N.N.W. from the town of Wilcannia. The first geological examination of these deposits was made in 1892, by Mr. J. B. Jaquet, who found that they occur in Upper Cretaceous rocks—the Desert Sandstone series.

As in the case of many other valuable mineral deposits, the precious opals of White Cliffs were discovered by accident. In the year 1889, a hunter, while tracking a wounded kangaroo, picked up a piece of the brilliantly-coloured mineral on the surface; after the find had been reported, a careful search of the locality was made, with the result that several more pieces were discovered; prospecting trenches were then excavated, and the gem was found *in situ*. Since that time mining operations have been carried on continuously, though sometimes under great difficulties, as in time of drought the locality is very badly provided with water; opal-mining has, however, now become a settled industry, and a thriving township has been established at White Cliffs. The area within which the mineral has been found in this district is about fifteen miles long by about two miles wide.

Prospecting for precious opal is a decidedly hazardous business, because, as a rule, there are no indications whatever on the surface of the occurrence of the mineral below. It is only in very rare instances that an outcrop of the gem can be seen, and the usual procedure is to dig a trench or pit in such a position as fancy may dictate, and trust to luck. Fortunately sinking is easy, as the rock is of a soft nature, and in a fair number of instances the opal has been met with at a very short distance from the surface, though a large majority of the pits are unsuccessful. For several years the belief existed amongst the miners that it was useless to prospect for precious opal at a greater depth than twelve feet from the surface, but of late the incorrectness of this view has been proved, and the stones have been discovered at a depth of nearly fifty feet.

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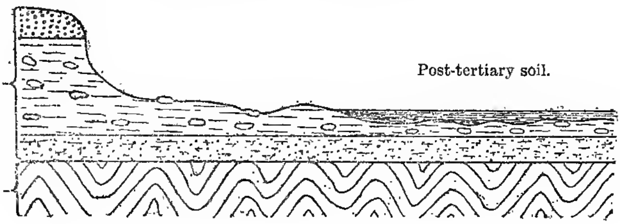
* Ann. Rept. Dept. Mines, N. S. Wales, for 1877, p. 207.

The Upper Cretaceous beds of White Cliffs rest unconformably on palæozoic slates, which are probably of Silurian age. These slates cannot be seen outcropping at the surface in the neighbourhood of the opal mines; but at Tarella Station, about fourteen miles distant, they have been intersected in two wells, put down for water, at depths of 127 and 143 feet respectively.

The lowest visible beds of the Upper Cretaceous series consist of coarse grits and sandstones; above these is a considerable thickness of fine white material, having much the appearance of kaolin or china




Section of Opal-bearing Rocks at White Cliffs.

clay, and containing occasional waterworn pebbles or boulders of considerable size. The latter consist of quartzite, and contain Devonian fossils (*Rhynchonella*, and *Spirifera*), showing that the Upper Cretaceous deposits of this locality have been derived from the denudation of Devonian rocks, several outcrops of which are known to occur at some distance from the field. The white matrix in which these boulders occur was for some time considered to be kaolin, but an analysis proved that it consists of nearly pure silica in a very finely-divided state, although careful examination of a number of samples has failed to reveal the remains of any organisms in it. Thin beds of loose sand (red or white), and also of gypsum, are occasionally present in this formation.

These beds pass upwards into conglomerates consisting of small pebbles in a matrix of the white siliceous material just alluded to. These fine conglomerates form the nearly vertical escarpments, sometimes twenty feet high, of the flat topped hills which are an important feature of the country. The surface of the lower ground is usually covered by a thickness of several feet of Post-Tertiary soil.

The precious opal occurs in the white siliceous rock forming the matrix of the conglomerates. It is sometimes met with in thin flat veins between the bedding planes of the rock; at other times it forms irregular shaped nodules, or deposits occupying joints; occasionally fragments of wood are found converted into common opal, while where cracks have occurred in the wood they have been filled by precious opal. Fossil bivalve shells and belemnites, entirely converted into precious opal, are not uncommon, and a fair number of opalised bones of *saurians* have also been found. Some of the boulders of Devonian quartzite have been similarly transmuted, and in one specimen about nine inches long, which has been presented to the Geological Museum, half the boulder, with its included fossil shells, has been infiltrated by opalising solutions which have filled all the interstices, while the other half consists of unaltered quartzite; the brilliant play of colours in the opalised portion produces a most beautiful effect. Although specimens such as these opalised fossils are of no intrinsic value as gemstones, they have acquired very high prices through the competition of dealers in curiosities, and are now extremely difficult to obtain. Another curiosity which is not uncommon is a pseudomorph of opal after groups of gypsum crystals; bunches of these several inches in length are sometimes found composed of precious opal, though the quality is usually poor.

The really valuable opal, however, which is cut and polished as a gem, is found in the irregular nodules and seams in the joints and fissures of the soft siliceous rock. When the miner finds the first indication of such a deposit, he proceeds with great care to excavate the soft rock from all round it, and occasionally masses worth several thousand pounds have been found in this way.

The following extracts are from a paper entitled "Some Notes on the White Cliffs Opal Fields" * by F. G. de V. Gipps. Mr. Gipps worked for a considerable time in the opal mines, and his statements in regard to the mode of occurrence and value of the stone are therefore of much interest:—

"Fully ninety-five per cent. of the opal obtained on the field is of no value, some of it being common or semi-opal, and much, although of the noble variety, containing little or no colour, being very cloudy or too watery, carrying the colour only in minute bars or streaks, or being stained a reddish-yellow by iron (the latter being known locally as *sandy-whisker*)." . . . . "In some instances I have found veins or seams of the colourless opal with the edges of the cracked and separated pieces coated with a thin film of finely-coloured opal. An unbroken vein of opal, however small, is never found; it having, after deposition, being broken into larger or smaller fragments, which, however, still retain their relative positions in the vein. This fracturing is evidently due to contraction on hardening, the same contraction having doubtless produced the internal strains of conchoidal relation to which the colouring of the opal is most probably due. With regard to the colour, however, I may mention that opal obtained in dark, damp, ferruginous clays, or in the thin bands of laminated ironstone which are of common occurrence, is generally darker and richer in colour than that from the white or light-coloured kaolins and siliceous beds. It is usually very clear in colour when in a band of gypsum (commonly known as copi), and especially so when the gypsum is crystallised, and where I have found it in contact with the gypsum crystals it has always the appearance

* *Trans. Aust. Inst. Mining Eng.*, 1894, II. pp. 70 79.

of having been eaten into by the gypsum. Lead, in the form of a mixed carbonate and sulphate with some gypsum, exists in many places on the field, occurring in small bun-shaped lumps of from $\frac{1}{4}$ to 1 lb. in weight all through the clays and kaolins, but I have been unable to trace any relation between this and the opal, and can offer no explanation of its occurrence in this form. These lumps of lead have always a small depression on the lower side, and a small cavity in the centre containing minute crystals of lead. The form is always the same, that of a bun with the flat or rather slightly concave side downwards. There is another peculiar form common on the field, known as a *nigger head.* These *nigger heads* are usually oval or spherical masses of more or less opal-impregnated, fine grained silica; they are of all sizes from 1 lb. to 1 cwt., and almost always contain a centre of opalised wood, often also containing opal of good colour in cracks caused by contraction."

"A similar material to that forming the *nigger head* is also found in masses containing wood and shells, and as *bandstone.* The *nigger heads* and masses containing shells and wood appear to be pseudomorphic after accretionary forms, and being always, or almost always, about a centre of opalised wood, in some cases with congeries of shells, like the mussels around wooden piles of piers, &c. . . . The *bandstones,* similar in composition to the above, appear to bear a marked relation to the opal deposits. They are flat bands, usually of harder nature than the adjoining strata, and often contain opalised shells, and sometimes belemnites, and have usually cracks which have been filled with opal. The seams of opal are usually formed either just above or below the *bandstone,* generally the latter. This *bandstone* has been the position for some considerable period of the bottom of the water, to judge by the shells, &c., it contains. A gradual deposit of mud of a finer nature than the rest, and subsequent drying or cracking, or the washing away of thin seams of some easily soluble matter, would provide cracks for subsequent deposition of opal. Both these operations have been at work I should judge from the mode in which the opal occurs, sometimes as a continuous horizontal vein (often with minute auxiliary inclined or vertical veins), sometimes as vertical veins of greater or less depth from a few inches to several feet, and sometimes as a broken vertical vein ramifying through a horizontal bed of perhaps two to six inches thickness, as if it had filled small cracks in mud around angular blocks and along irregular lines such as we may see in any temporarily dry mud flat. There may be more than one *bandstone,* one being sometimes two or three feet, or more, below the other. The *nigger heads,* likewise looked upon as a good indication of opal, also naturally occur at what has been the sea bottom for some considerable period. Where the opal in these indicators is of good colour, it is likely to be so also in the veins which occur near them. . . . I have frequently observed various matters, such as small particles of ironstone, clay, &c., held in suspense in clear opal, as in the case of ants and flies in amber. This is especially noticeable in some of the opalised wood, fragments of wood, &c., being scattered about in the large veins of clear opal which some of it contains. . . . When the colour of the individual stones varies, or is *not true*, in the vertical seam it is banded across the stone, in the horizontal veins it is along the stone; the bands of colour, whether in the vertical or flat veins, being as nearly as possible horizontal, thus differing from the usual arrangement of veins of siliceous or other matter, which are generally banded from the sides towards the centre, especially when vertical. . . . I have seen many vertical veins with half an inch to an inch of good opal at the top, but with that immediately below discoloured by foreign matter, and often quite opaque and stony looking. In no instance have I seen this order reversed—that is, the base stuff on top and good opal below, though it is often *not true*—that is to say, it is in horizontal bands of varying colour. Owing to this, as a general rule, the vertical veins, even when consisting of good coloured opal, are not of such good quality as the horizontal" . . . . . .

"There is a wonderful variety of opal found on the field, and the prices paid locally run from zero to £25 per ounce, the ounce being the unit for purchasing in the rough. It is rarely that the price paid exceeds £20 per ounce.

"In valuing opal a good many points have to be taken into account. Needless to say *colour* is the first. Red fire, or red in combination with yellow, blue, and green being the best. Blue by itself is quite valueless, and green opal is not of great value unless the colour is very vivid and the *pattern* good."

"That the colour should be *true* is a vital point. However good it may be, if it runs in streaks or patches, alternating with colourless or inferior quality, that is *untrue*, it is of comparatively small value."

"*Pattern* is an important factor in the value, the various kinds being distinguished respectively as *pinfire*, when the grain, if I may so call it, is very small; *harlequin*, when the colour is all in small squares, the more regular the better; and *flashfire*, or *flash opal* when the colour shows as a single flash or in very large pattern. Of course there are many intermediate classes."

"The *harlequin* is the most uncommon, and also the most beautiful. When the squares of colour are regular, and show as distinct minute chequers of red, yellow, blue, and green, this class of opal is truly magnificent."

"The *flash opal* is often very beautiful in colour, especially when of the true ruby or pigeon's blood colour. As a rule, however, it shows green, or red flash according to the angle at which it is held."

"The *direction* of the pattern has also to be considered. Often a stone that shows a very good *edge* pattern will not look nearly so well on the *face*, whilst a stone which shows somewhat streaky in the shorter direction on the *edge* will sometimes give a fine *harlequin* pattern on the *face*. On this account the shape of the stone comes into the reckoning. Thus a thick stone with a good edge pattern may often be cut up so as to use that pattern as a face to all the stones cut from it, whilst a thin stone, though of equally good edge pattern, which could only be cut with the natural face, would probably not be worth nearly as much weight for weight."

"It is difficult to obtain separate stones of absolute similarity in colour and pattern, therefore, for suites of jewellery, a large true stone from which the whole could be cut is worth a great deal more per ounce than so many smaller stones approximately similar. Again, the *ground* or body of the opal must be taken into account. This is not a constant quantity, as the various patterns require slightly different ground. It should neither be too transparent nor too opaque, almost clear, with a slight milky tinge, translucent, being about the best ground in general. Some of the opal is more brittle than other. Of course, the harder and tougher the stone the better it is, as, when cut, it is less likely to be injured, and retains the polish better." . . . . . . .

"Some months ago (1894) a piece of opal five and one quarter ounces in weight, of beautiful colour and pattern, and perfectly true, was found by Messrs. Gonevey and Gladstone, tributors on Block 6, one of the leases held by the Wilcannia Syndicate. In shape the stone was almost square, and was over an inch thick. This piece of opal was sold to one of the buyers who periodically visit the field for £100, or about £20 per ounce, which is considered locally a high price for first-class opal. The buyer must, in such a case, make a phenomenal profit. Since then a piece of first-class opal weighing over seven ounces, a truly magnificent stone, was discovered on Block 2, the property of the Mackenzie Brothers. This stone weighed originally over ten ounces, but was unfortunately broken in two by a blow from the pick of the man who discovered it. It was valued at £700, but was sold, I understand, for considerably less. Besides these two, a good many first-class stones have been found in different parts of the field upwards of three ounces in weight. As a general rule, however, when very large stones are found, even if they carry colour, it is faint or untrue."

The Upper Cretaceous rocks cover considerable areas of the north-western portion of New South Wales, and there is good reason for believing that deposits of precious opal will be found in other localities besides White Cliffs. A tendency to opalisation is one of the characteristics of the Desert Sandstone formation, and it seems to be evident that since the deposition of these rocks they have been materially transmuted by the action of hydrothermal springs, which filled up all their interstitial spaces with hydrous silica. The reason why this hydrous silica is, in some places, characterised by the brilliant play of colour which constitutes it precious opal, while in other localities the colours are entirely lacking, is a problem which is not yet understood; but patient prospecting will doubtless lead to the discovery of a number of other deposits similar to that of White Cliffs.

The following is a list of the fossils, from the Upper Cretaceous rocks of White Cliffs, which have been identified by Mr. W. S. Dun, Palæontologist to the Geological Survey. Specimens of all these fossils, with the exception of those marked with an asterisk, have been obtained in an opalised condition :—

Lucina (?) Bonythoni, *Tate.*
Platopsis (?) corrugata, *Tate.*
Belemnites Canhami, *Tate.*
Natica variabilis, *Moore.*
Modiola.
Tellina.
*Maccoyella reflecta, *Moore.*
Maccoyella Barklyi, *Moore.*
Glycimeris.
Cytherca, *cf.* Moorei. *Eth. fil.*
Cimoliosaurus leucoscopelus, *Eth. fil.*
Crinoid ossicles.
Brachiopod fragments.
Coniferous wood.
*Indeterminable gasteropod and bivalves

*Production of Opal.*

| Year. | Quantity. | Value. |
|---|---|---|
| | lb. | £ |
| 1890 ... ... ... ... | 195·00 | 15,600* |
| 1891 ... ... ... ... | ...... | ...... |
| 1892 ... ... ... ... | 41·67 | 2,000 |
| 1893 ... ... ... ... | 449·35 | 12,315 |
| 1894 ... ... ... ... | 198·00 | 5,684 |
| 1895 ... ... ... ... | 333·00 | 6,000 |
| 1896 ... ... ... ... | 1,390·00 | 45,000 |
| 1897 ... ... ... ... | 5,292·00 | 75,000 |
| 1898 ... ... ... ... | ...... | 80,000 |
| 1899 ... ... ... ... | ...... | 135,000 |
| Total ... ... ... | ...... | £376,599 |

* I believe this amount to be altogether excessive. Annual Report of 1890 says that "*as much as* £5 an oz. had been offered locally (*i.e.* on the field) for good specimens"; and that during the year 195 lb. had been raised. This has evidently been valued all round at the "as much as" price. 195 × 16 × 5 = £15,600.

# EMERALD.—BERYL.

The emerald is a variety of beryl, the only distinction being in the colour of the stone; in the gem it is bright emerald green, due to the presence of a little chromium, while the colour of the mineral known as beryl is pale green passing into light blue, yellow, white, and sometimes pale rose. Emerald crystallises in hexagonal prisms; its composition is silicate of alumina and glucina, $Be_3Al_2Si_6O_{18}$ = silica 67 per cent., alumina 19 per cent., and glucina 14 per cent.; lustre vitreous, sometimes resinous; hardness, 7·5—8; specific gravity, 2·63—2·80; streak white; transparent to subtranslucent; frequently contains flaws, but when free from these and of a good colour it is very highly prized as a gem.

Emerald occurs near Ekaterinburg, in Siberia, in mica schist; at Salsburg in the same rock; in the United States of Columbia in clay-slate; and in North Carolina (U.S.A.) in pegmatite intruding mica schist. Beryl occurs in many parts of the world in veins of pegmatitic granite.

*Aquamarine* is the name given to beryl of a bluish-green colour.

The *Oriental emerald* is a green variety of sapphire.

*The occurrence of Emerald in New South Wales.*—A true emerald is said to have been obtained some years ago at Kiandra, but a certain amount of doubt attaches to the statement. In 1890 emeralds were recognised by Mr. D. A. Porter, of Tamworth, at a locality about nine miles north by east of the township of Emmaville, in the County of Gough. The deposit was originally taken up for tin, and was known as "Cleary's Lode." The country in the neighbourhood consists of indurated claystones (probably of Carboniferous age) which have been intruded by granite. The junction of the intrusive granite *massif* with the claystones occurs about three-quarters of a mile to the north of the Emerald Mine, and it is in a dyke or offshoot from the granite that the emeralds occur. The dyke itself varies from a few inches up to four feet in width; in places it is composed of typical greisen, but at the Emerald Mine it is of the character of a pegmatite. The walls of the dyke are composed of the claystones.

A report on this deposit was made by Professor David in 1891*, when the mine was being worked. He stated that the specific gravity of the stones was 2·670, and that it was evident that they were green beryls of a colour sufficiently emerald-green to entitle them to be termed emeralds. The emeralds were found to be intercrystallised with topaz,

* *Ann. Rept. Dept. Mines for* 1891, pp. 229-234.

frequently penetrating crystals of fluor spar, as delicate acicular prisms. Sometimes embedded in a kaolinised felspathic rock, occasionally quite surrounded by massive mispickel, rarely encrusted with crystals of tinstone, and in one case traversing plates of mica.

The dyke or vein followed a direction about E. 40° N., and was dipping at an angle of about 77° to the south-east. A shaft which had been sunk by the Emerald Proprietary Company had attained a depth of fifty feet at the time of Professor David's visit, and a shoot of emeralds had been struck near the surface and was pitching to the north-east, so that at a depth of thirty-three feet it had passed into the north-eastern wall of the shaft. A drive had been put in for four or five feet to follow the *chute*, and the sectional dimensions of the shoot here were about seven feet by fifteen inches. It is understood that this *chute* cut out, or was lost at about the fifty feet level. The shaft was afterwards continued to a depth of several hundred feet, without discovering a fresh *chute*, and several other excavations were made along the course of the dyke without obtaining any very satisfactory results. The mine has been idle for a considerable time, but it is rumoured that the proprietors intend to reopen it shortly. There is every reason to believe that similar *chutes* of emeralds will be found if the dyke be systematically prospected, and there are other granite dykes in the vicinity which appear to occur under precisely similar conditions to the one in which the emeralds were discovered. It is to be hoped, therefore, that the emerald mining industry will yet be established in this district.

According to Professor David's report the largest emerald discovered up to the time of his visit was embedded in mispickel. It was found in the Emerald Proprietary's Extended Mine, and was estimated to weigh about 23 carats. The crystal was $1\frac{1}{4}$ inch long, by about $\frac{3}{10}$ of an inch in diameter; it was, however, divided by several transverse cracks, following the planes of basal cleavage.

The weights of the largest cut and polished gems from the mine were given in April, 1891, as follows:—

$2\frac{1}{8}$ carats (£15 stated to have been offered for this gem).
$1\frac{1}{2}$ ,,
$1\frac{1}{4}$ ,,
$1\frac{1}{8}$ ,, (£5 stated to have been offered for this).
$1\frac{1}{8}$ ,,
1 ,,
1 ,,
$\frac{3}{4}$ ,,

Altogether about fifty carats were understood to have been cut and polished, and Professor David was informed by the proprietors that they had been offered from £2 to £2 2s. per carat for the parcel. The largest emerald in the rough from the Proprietary Mine weighed nine carats, another weighed six and a half carats, a third six carats, and a fourth five carats.

The colour was described as varying from faint shades of green up to moderately bright emerald green, but never showing a very deep shade of green. In a few of the crystals the colouring material was unequally distributed, in places colourless bands appeared in the crystals running at right angles to the principal axis. The colour of a great number of crystals was described as that of green beryl rather than of true emerald.

It was intimated that the *chute* yielded about 1,000 carats of beryls and emeralds per running foot, and Professor David was of opinion that of these from ten to twenty in the thousand might be assumed to be gems of good colour and fairly free from flaws, and that, perhaps, three per cent. of the remainder might have some commercial value when cut and polished.

Beryl has been found at Elsmore associated with quartz and tinstone; at Mole Tableland (Gulf Stream Company's Mine) with quartz and tinstone; at Ophir, County of Wellington, with felspar, quartz, and mica; at the Shoalhaven River, east of Bungonia; also in alluvial deposit at Emmaville, Kangaroo Flat, Tingha, Cope's Creek, and Scrubby Gully. (David.)

*Production of Emeralds.*

The following statements are taken from the Annual Reports of the Department of Mines:—

1890. "The occurrence of emeralds at The Glen (Emmaville) was discovered, and 2,225 carats were forwarded as a trial shipment to London. Some of the gems sold at £4 per carat."

1891. "25,000 carats raised during the year."

1892. "About 25,000 carats, value unknown, were obtained from the Emerald Proprietary's Mine, situated at The Glen, near Emmaville. The hardness of the matrix in which the emeralds are found is still a source of difficulty, as it is almost impossible to break down the rock without injuring and frequently destroying the emeralds."

1894. "The Emerald Proprietary Company's Mines at The Glen, near Emmaville, have not been worked during the year in consequence of the unprofitable returns from stones sent to the London market."

1897. "The Emerald Mine, near Emmaville, has been taken up again, and sinking is being proceeded with, it being the intention of the present owners to test the deposit at a depth. There were no gems produced during the year."

1898. "The Emerald Mine, near Emmaville, which was worked for some time during the year, has now obtained suspension of the labour conditions. A great amount of work has been done on this mine, and some £5,000 has been expended on it."

# TURQUOISE.

The composition of turquoise is hydrous phosphate of alumina ($2Al_2O_3 \cdot P_2O_5 \cdot 5H_2O$) coloured by hydrous phosphate of copper ($2CuO \cdot P_2O_5 \cdot 4H_2O$). In its mode of occurrence it is massive, amorphous or cryptocrystalline, reniform, stalactitic, or encrusting. Its hardness is 6, and its specific gravity varies from 2·6 to 2·83. Its lustre is feeble, somewhat waxy ; its colour varies from sky-blue to bluish-green, apple-green, and greenish-gray ; its streak is white or greenish. It is feebly subtranslucent to opaque.

The best turquoise is found in narrow seams ($\frac{1}{12}$ to $\frac{1}{4}$ inch in thickness), or irregular patches in porphyritic trachyte and clay-slate, at a locality situated to the north-west of the village of Maden, in Persia. It also occurs with limonite, in seams in porphyry in the Megara Valley, Sinai. Turquoise of inferior colour (greenish-blue) is found in Siberia and in Turkestan, with limonite, in seams in clay-slate. In America, the gem is also found in Los Cerillos and the Burro Mountains in New Mexico.

The name turquoise means *a Turkish gem*, in reference to the fact of its having come into Europe through Turkey.

*Occurrence in New South Wales.*—Turquoise was discovered in 1894* near Bodalla, on the northern bank of Mummuga Creek, in the Parish of Bodalla, County of Dampier. The country here consists of highly altered slates and quartzites (probably of Upper Silurian age) ; the slates strike north and south, and are traversed by a series of joints having an east and west direction. The turquoise occurs chiefly as thin veins, from $\frac{1}{16}$ to nearly $\frac{1}{4}$ of an inch in thickness in the joints of the slate. The colour of most of the mineral hitherto found is not sufficiently good to render it marketable, being of a bluish-green instead of the sky-blue, which makes turquoise a highly-prized gem. Some of the stones, however, are of fair colour, and lend encouragement to the hope that further prospecting may result in the discovery of more valuable material. The amount of exploratory work done is really very small, and the indications appear to justify a greater expenditure than has been incurred by the owners of the mineral lease, Messrs. Joubert and Party.

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* *Records Geol. Survey N.S. Wales*, iv., Part I, p. 20.

# SAPPHIRES, AND OTHER GEMS.

THE sapphire and the ruby are pure coloured varieties of corundum. They crystallise in the hexagonal or rhombohedral system, and their composition is alumina, $Al_2 O_3$=aluminium 52·9 per cent., oxygen 47·1 per cent. Their hardness is 9, which is equivalent to saying that they can only be scratched by the diamond; their specific gravity varies from 3·95 to 4·10; their lustre is adamantine to vitreous, and sometimes pearly on the terminal plane of the crystal; they are transparent to translucent. The colour of pure corundum varies from blue, to red, yellow, brown, gray, and nearly white; streak uncoloured. The following gems are all varieties of this mineral, and are named according to their colour; the *Sapphire*, blue; the *Oriental Ruby*, red; the *Oriental Topaz*, yellow; the *Oriental Emerald*, green; the *Oriental Amethyst*, purple.

These gems are usually found in crystalline rocks such as limestones, dolomites, gneiss, granite, mica-slate, chlorite slate, etc., and also in river gravels derived from the denudation of these rocks. The best rubies occur in crystalline limestones in the neighbourhood of Mogok, in Upper Burma. Fine sapphires occur in the Zanskar Range in the Kashmir Himalayas, and also in Ceylon.

*New South Wales occurrences.*—The first record of the discovery of sapphires in Australia is contained in a report (dated Burrandong, 18th October, 1851), by the late Mr. S. Stutchbury, to the Colonial Secretary; he says:—"In the watercourses I have found or had shown to me the following gems, but from their small size they were not of any value."

*Topazes.*—White.

*Garnets.*—Almandine.

*Rubies.*—Two varieties; the spinelle ruby, and the balas ruby.

*Sapphires.*—Three varieties; light blue (salamstein), dark blue, and the asteria or star-sapphire.

*Chrysoberyl.*

*Chrysolite*, and its variety olivine brown rock crystal.

*Cairngorm.*

"Sapphires have been found in the Macquarie and Cudgegong Rivers, the salamstein at Bunbejong, and the asteria or star sapphire was found at the Frederick's Valley Creek."

The Revd. W. B. Clarke, in 1853, mentioned the occurrence of "spinelle rubies, oriental emeralds, sapphires and other gems" with stream tin in the neighbourhood of Inverell, *vide* report on *The geological structure of the Western Slopes of the highlands of New England.*

Since that date sapphires have been found in Tertiary and Post-Tertiary alluvial deposits, containing gold and tin, in many parts of the country, but it is only in rare instances that the stones possess sufficiently good colour to render them valuable as gems; the majority of the sapphires have a greenish-blue or bottle-green tint, and most of those which are pure blue by transmitted light are of such a deep shade that they appear almost black when seen by reflected light.

Sapphires of indifferent quality are especially numerous about seventeen miles to the east of Inverell, so much so that the name Sapphire has been given to the locality. A specimen of weathered basalt from this district containing a crystal of sapphire embedded in it was presented to the Revd. J. M. Curran, who has since stated* that in his opinion basalt is the true matrix of the sapphire. This opinion may, of course, prove to be correct, but in the meantime more evidence is needed to confirm it. It is true that the sapphires in alluvial deposits are frequently found in proximity to basalt, but it must be remembered that this rock was originally in the form of molten lava, which invaded and filled up the Tertiary watercourses, and that in some (at any rate) of these watercourses sapphires were present prior to the influx of the lava. It is quite conceivable therefore that the sapphire in Mr. Curran's possession may have been caught up from a creek-bed by the lava when in a plastic condition. If basalt be the true matrix of the gem, it is natural to suppose that in a district such as the one referred to, where both sapphires and basalt are exceedingly plentiful in juxtaposition, other specimens of the stone in the matrix would not be difficult to obtain. Nevertheless, the author has spent a considerable amount of time in examining the basalt there for crystals of sapphire, but without success. While, therefore, it is desirable that the interesting specimen in Mr. Curran's possession should be recorded, it is probably premature to assume that the matrix of sapphire in this country is different to what it is in other parts of the world.

*List of Localities where Sapphires occur.*

| | |
|---|---|
| Abercrombie River. | Oban. |
| Ben Lomond. | Peel River. |
| Berrima. | Puddledock. |
| Bingara. | Rose Valley, near Emmaville. |
| Cope's Creek. | Scrubby Gully, County of Gough. |
| Cudgegong River. | Severn River. |
| Dundee. | Shoalhaven River. |
| Glen Elgin. | Snowy River. |
| Gwydir River. | Swanbrook, } County of Gough. |
| Inverell. | Swanvale, } County of Gough. |
| Mann River. | Swamp Oak, County of Arrawatta. |
| Mittagong, near. | Tingha. |
| Mole Tableland. | Tumberumba. |
| Mount Werong. | Two-mile Flat (Cudgegong River). |
| Namoi River. | Uralla. |
| Native Dog Creek, near Oberon. | Vegetable Creek. |
| Newstead. | Wingecarribbee River. |
| Nundle. | |

* Journ. Roy. Soc. N. S. Wales for 1896, xxx, p. 235.

The finding of *rubies* was recorded in the early writings of both Stutchbury and Clarke; but it appears that in most, if not all instances, the mineral referred to was a variety of *spinelle*, which is an aluminate of magnesia, and not the *oriental ruby*, the composition of which is pure alumina. Probably the first authentic record of the occurrence of the oriental ruby was in 1870 by Messrs. Taylor and Thompson,* who identified small specimens of the gem (one-tenth of an inch in diameter) in the diamantiferous gravels of the Cudgegong River. The colour of the stones was pink, passing into violet; their hardness and specific gravity were determined, and an analysis which was made by Professor Thompson gave the following composition:—

| | |
|---|---|
| Alumina ... ... ... ... ... ... | 97·90 |
| Ferric Oxide... ... ... ... ... ... | 1·39 |
| Magnesia ... ... ... ... ... ... | ·63 |
| Lime ... ... ... ... ... ... ... | ·52 |
| | 100·44 |

Finally it may be said that while oriental rubies undoubtedly do occur in some of the old river gravels, there is no authentic record of the discovery of crystals of sufficient size and purity of colour to be valuable as gemstones.

*Topaz.*—Composition alumina, fluorine, and silica = $Al_{12}Si_6O_{25}F_{10}$. Crystallises in the rhombic system; hardness = 8; specific gravity, 3·4—3·65; lustre, vitreous; colour, straw yellow, wine yellow, white, grayish, reddish, greenish, and bluish; streak, uncoloured; transparent to sub-translucent. Topaz occurs usually in gneiss or granite with tourmaline, mica, and beryl, and occasionally with apatite, fluorspar, and tinstone. In Brazil it also occurs in talcose rock and mica slate; less frequently it is found in cavities of rhyolite.

*Occurrence of Topaz in New South Wales.*—Waterworn specimens of topaz are found in Tertiary and Post-Tertiary gravels in many localities, and well developed crystals also occur, associated with tinstone, in granite and greisen in the Inverell, Emmaville, and Mole Table-land Districts. At the Emerald Mine, nine miles north by east of Emmaville, fine colourless transparent crystals were found associated with emerald, beryl, fluorspar, mispickel, kaolin, and tinstone in a pegmatite dyke traversing indurated claystones. Many of the New England topazes have a beautiful pale blue colour and are of large size. Professor Liversidge states† that a portion of a large bluish-green crystal found at Mudgee weighed several pounds; also that one found at Gundagai, of a pale blue-green tint, measured three by one and a half inches, and weighed 11 oz. 5 dwt., while another of a similar colour from Gulgong weighed 18 oz. avoirdupois.

* *Trans. Roy. Soc. N. S. Wales, for* 1870, pp. 94—106.
† *Minerals of New South Wales.*

*List of Localities where Topaz has been found.*

| | |
|---|---|
| Abercrombie River. | Glen Creek. |
| Balala. | Gulf, The. |
| Bathurst. | Inverell. |
| Bell River. | Lachlan River. |
| Bingara. | Macquarie River. |
| Boggy Camp. | Mole Tableland. |
| Boonoo Boonoo Creek. | Oban. |
| Cooyal. | Rocky River, Uralla. |
| Cope's Creek. | Scrubby Gully, County of Gough. |
| Cudgegong River. | Shoalhaven River. |
| Dundee. | Two-mile Flat, Cudgegong River. |
| Elsmore. | Vegetable Creek. |

*Zircon.*—Composition silicate of zirconia, $ZrO_2$ $SiO_2$ = silica, 32·8 per cent., zirconia, 67·2 per cent. Crystallises in the tetragonal system, generally in square prisms. The zircon has a hardness of 7·5, and its specific gravity varies from 4·2 to 4·86; its lustre is adamantine; it is colourless, pale yellow, greyish, yellowish-green, brownish-yellow, and reddish-brown. The orange, reddish, and brownish varieties are termed hyacinth. The mineral is transparent to sub-transparent, and opaque; its streak is uncoloured. Zircons are often mistaken for diamonds by the uninitiated on account of their brilliant lustre.

*Occurrence in New South Wales.*—Zircons of small size are extremely common in the auriferous and stanniferous gravels in different parts of the country, but large stones are comparatively rare. The beach sands of the northern coast (the Richmond and Evans Rivers), which contain platinum and tin, are largely composed of minute grains or crystals of zircon. The largest specimens of this mineral are found in the neighbourhood of Hanging Rock (Nundle); they are colourless and transparent, and possess such a fine lustre that the gold-miners have frequently mistaken them for diamonds.

*Garnet.*—Composition variable, silicate of alumina or iron, with lime, magnesia, or manganese. The commonest varieties of garnet are *grossularia* (silicate of alumina and lime), *pyrope* (silicate of alumina and magnesia), *almandine* (silicate or iron and alumina), and *spessartite* (silicate of alumina and manganese). Garnets crystallise in the cubical system, in the form of rhombic dodecahedrons; they are also found massive, granular, and compact (garnet rock). Their lustre is vitreous to resinous; colour red, brown, yellow, white, apple-green, and black; streak white; they are transparent to sub-translucent. Their hardness is 6·5 to 7·5, and their specific gravity varies from 3·15 to 4·3, according to composition.

*Occurrence in New South Wales.*—Garnets are of common occurrence in many parts of this country, and they vary in size from minute grains to crystals of one inch or more in diameter; but stones suitable for cutting and polishing as gems appear to be rare, and so far they have not been regarded as of commercial importance.

The association of diamonds with a garnet-felspar-pyroxene rock (eclogite) at Ruby Hill, near Bingara, has already been referred to. Almandine garnets are found in the Triassic sandstones near Sydney and also in the Narrabri District; spessartite is of common occurrence in the Broken Hill Silver lode; massive garnet rock, containing bunches of magnetic iron-ore, occurs on the Irondale Estate, near Wallerawang; and in many other localities crystals of garnet are to be seen (as a result of contact metamorphism) at the junction of intrusive rocks with limestones. In view, therefore, of the wide spread occurrence of this mineral it is not surprising to find that it is a common constituent of alluvial gravels of Tertiary and Post-Tertiary age.

# PLAN
## shewing the Alunite deposits
## AT BULLAH DELAH MOUNTAIN

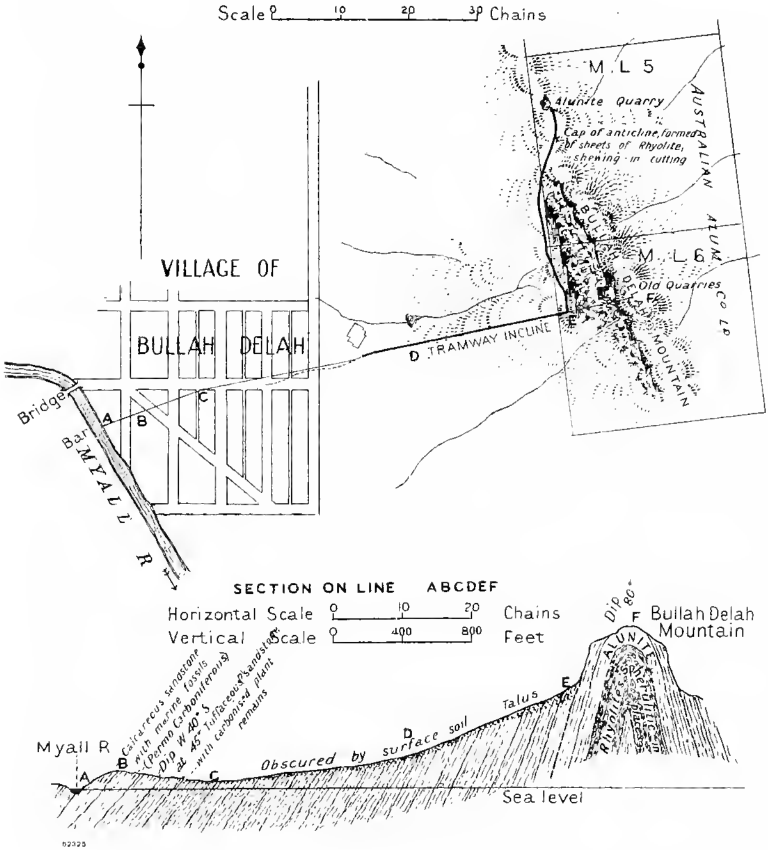



*Photo-lithographed by*
*W. A. Gullick, Government Printer,*
*Sydney, N.S.W.*

# ALUNITE OR ALUMSTONE.

THE mineral Alunite crystallizes in rhombohedrous; it also occurs massive, having a fibrous, granular, or impalpable texture; its fracture is flat conchoidal, uneven, sometimes splintery, and occasionally earthy; it is brittle; its hardness varies from 3·5 to 4; its specific gravity is from 2·58 to 2·75; its colour varies from white to gray, pink, or red; its streak is white, and it is transparent to sub-translucent. Its composition, when pure, is hydrous sulphate of alumina and potassium = $K_2O \cdot 3Al_2O_3 \cdot 4SO_3$, or Potash = 11·4 per cent., Alumina 37·0, Sulphuric anhydride 38·6, and water 13·0.

It is usually found forming seams in trachytic and allied rocks, where it has been formed as a result of the alteration of the rock by means of sulphurous vapours.

*Foreign occurrences* (according to Dana).—Met with at Tolfa, near Civita Vecchia in the neighbourhood of Rome, in crystals; at Montioni in Tuscany; at two localities in Hungary; at three localities in the Grecian Archipelago; with opal at Santorin; at Mt. Dore, in France; near Hadji-Khan, Buchara; and with hyalite and opal at Queretaro, in Mexico. "In the United States it occurs, associated with diaspore, in rhombohedral crystals, at Rosita Hills, Custer Co., Colorado. The crystals are dull and opaque, with rough faces, and consist of alunite, but with a granular structure, they being pseudomorphs after an earlier formation of alunite. The formation of the alunite is explained by the action of sulphurous gases upon the highly aluminous andesites. The compact varieties from Hungary are so hard as to admit of being used for millstones. Alum is obtained from it by repeatedly roasting and lixiviating, and finally crystallising by evaporation."

*Alunite in New South Wales.*—What is probably one of the most remarkable deposits of alunite in the world occurs east of the township of Bullah Delah, in the Parish of Bullah Delah, County of Gloucester.

It consists of a narrow mountain range (about three miles long, and having a maximum altitude of nine hundred feet), which for a mile or more of its length is composed almost entirely of the mineral alunite of greater or less purity.

In the centre of the township of Bullah Delah are seen beds of yellowish gray calcareous sandstones, containing numerous fossils belonging to the (Upper ?) Marine Series of the Permo-Carboniferous System. These beds dip W. 40° S. at 45°, and are succeeded (conformably) on the east by thick-bedded strata, consisting of fine-grained bluish-gray (tuffaceous?) sandstones, containing a few carbonised plant remains, and occasional waterworn pebbles of quartz felsite.

Between these beds and the mountain range, a distance of less than a mile, the rocks are, for the most part, obscured by soil, &c., but here and there beds of this sandstone are seen to outcrop, showing that it forms an important feature in the series. The sides of the mountain, for a height of five hundred feet, are formed of a steeply sloping talus, consisting of fallen alunite rock, which effectually obscures the underlying formation. Above this, for a height of four hundred feet, the central escarpment of the mountain range is apparently formed of a steep anticline, the beds of alunite on both sides of the summit being inclined in opposite directions at angles of 80°–83° with the horizontal. Although the planes of bedding have been almost entirely obliterated, rough traces of them can be distinguished in places. A slight cutting has been made, on a gap on the range, for a tramline to the alunite quarry, and in this excavation the rocks underlying the alunite have been exposed in the form of a distinct arch or anticline, and these rocks consist of rhyolites, which show spherulitic structure in places. Further away to the south of the range there is a great development of these rhyolites, which exhibit remarkable flow structure, and in places are spherulitic, the spherules being occasionally an inch or more in diameter. Masses or dykes of volcanic glass (obsidian) are also seen at intervals in the rhyolites. On the eastern side of the range there is an area of the Permo-Carboniferous coal measures, and at least two seams of coal outcrop near the north-western corner of Portion 67, Parish of Bullah Delah.

It seems evident that the rhyolites are interbedded with the Permo-Carboniferous rocks, and that they were deposited as contemporaneous lava sheets.

The alunite range, which is about three miles long, and very narrow, has a singularly symmetrical outline when viewed from the town. A large almost perpendicular crown of alunite, four hundred feet high, occupies the centre, while at intervals along the backbone of the ridge, to the north and south of this, are other projecting crags of the same material but of lesser height. The range slopes gradually downwards to its northern and southern extremities. Between the projecting crags are gaps or saddles, which are occupied by dykes of dolerite, trending across the range. The saddles have, in fact, been formed owing to the tendency of the dolerite to decompose more rapidly than the alunite rock.

In view of the fact that both sides of the summit of the mountain are formed of the same bed, owing to the sharp fold of the anticline, it seems probable that the alunite will be found to extend below the talus of fallen rock and soil which slopes from the base of the cliff towards the undulating plain.

*Photographed by E. F. Pittman.*

DEPOSITS OF ALUNITE AND THE AUSTRALIAN ALUM COMPANY'S TRAMWAY, BULLAH DELAH MOUNTAIN.

Although the range may be said to be almost entirely composed of the mineral alunite, it must not be supposed that it is all of a quality suitable for commercial purposes; on the contrary, it differs materially in its composition, the most impure variety being the most abundant. At the same time, considering the comparatively small amount of prospecting work that has been performed, there is evidence of the occurrence of large deposits of high grade mineral.

The impure alunite contains occasional waterworn pebbles of quartz felsite, similar to those previously mentioned as occurring in the bluish-gray sandstones of the Permo-Carboniferous beds. In some places stalactitic or concretionary forms of alunite are seen, and at intervals the mineral is marbled by wavy and more or less concentric markings, such as would be produced by the gradual percolation of solutions.

A yellowish, waxy-looking mineral, which appears as segregated masses in the alunite in places, has the following composition, according to the Analyst to the Department of Mines :—

| | |
|---|---|
| Moisture at 100° C. ... ... ... ... ... | 1·24 |
| Combined water ... ... ... ... ... | 13·42 |
| Silica ($SiO_2$) ... ... ... ... ... | 45·84 |
| Alumina ($Al_2O_3$) ... ... ... ... ... | 39·58 |
| Magnesia ($MgO$) ... ... ... ... ... | ·15 |
| Potash ($K_2O$) ... ... ... ... } Soda ($Na_2O$) ... ... ... ... | ·19 |
| Phosphoric Oxide ($P_2O_5$)... ... ... ... | ·04 |
| | 100·46 |

It is evident, therefore, that the mineral is Halloysite.

Four varieties of alunite are recognised by the Manager of the Mines, viz. :—

| | | | | |
|---|---|---|---|---|
| (1.) "Light Pink," | containing | 1·7 | per cent. | of silica. |
| (2.) "Chalk White," | ,, | 16·4 | ,, | ,, |
| (3.) "Purple," | ,, | 19·5 | ,, | ,, |
| (4.) "Granular," | ,, | 39·5 | ,, | ,, |

The light-pink variety is much the best as regards percentage of alumina, but some of it carries badly, being very brittle, and, consequently, making much "smalls" in transit. It is an exceedingly pretty waxy-looking mineral of a bright pink colour; it occurs in patches, sometimes showing as thin veins, and splashes, at others being massive, and many feet in width. Only the pink ore is at present worked, and shipments are kept below 10 per cent. of silica contents.

In the main quarry a face of sixty feet in width is being taken out, and the stone is subjected to rough hand-picking before being loaded into trucks, the "purple" and "chalk white" ore being discarded. It is carried by a horse-tram to the base of the central escarpment, and is then sent down an incline, worked on the main and tail-rope system, on the slope of the talus. From the bottom of the incline it is conveyed in carts to the wharf on Myall River, half a mile distant, whence it is shipped to England for the manufacture of alum. The works are situated at Runcorn, on the Manchester Canal, and the mines are owned by the Australian Alum Company (Limited).

Typical samples of the four varieties of mineral were selected at the mine, and were analysed in the Laboratory of the Department of Mines, with the following results :—

| | "Light Pink." | "Chalk White." | "Purple." | "Granular." |
|---|---|---|---|---|
| Moisture at 100° C. ... ... ... | ·06 | ·46 | ·16 | ·22 |
| Combined water ... ... ... | 13·19 | 13·86 | 9·65 | 10·26 |
| Silica ($SiO_2$) ... ... ... ... | 1·92 | 19·34 | 32·40 | 23·45 |
| Ferric Oxide ($Fe_2O_3$) ... ... ... | ·26 | ·27 | ·07 | ·04 |
| Alumina ($Al_2O_3$) ... ... ... | 37·52 | 37·37 | 25·91 | 30·17 |
| Lime (CaO) ... ... ... ... | Nil. | Nil. | ·07 | ·01 |
| Magnesia (MgO) ... ... ... | Nil. | Nil. | trace. | trace. |
| Potash ($K_2O$) ... ... ... ... | 9·51 | 5·68 | 6·53 | 8·00 |
| Soda ($Na_2O$) ... ... ... ... | 1·12 | 1·08 | ·82 | ·63 |
| Sulphuric anhydride ($SO_3$) ... ... | 36·76 | 22·09 | 24·47 | 26·88 |
| Phosphoric anhydride ($P_2O_5$) ... | trace. | trace. | ·02 | ·07 |
| Chlorine (Cl) ... ... ... ... | trace. | trace. | trace. | trace. |
| | 100·34 | 100·15 | 100·10 | 99·73 |

*Origin of the Deposit.*—It has already been mentioned that deposits of alunite in other parts of the world, where their mode of occurrence has been studied, are believed to have been formed by the action of sulphurous vapours upon trachytic and other allied igneous rocks.

At Bullah Delah everything points to the rhyolites as the origin of the alunite. They occur interbedded with the Permo-Carboniferous rocks in the form of contemporaneous lava sheets, and it is probable that the whole series of sandstones and lava sheets was folded into the form of an anticline by earth movements. Subsequently during the Tertiary period these rocks were intersected, in an east and west direction, by a number of dolerite dykes. These later volcanic intrusions were probably attended or followed by evolutions of steam and sulphurous acid vapours, and it is reasonable to suppose that it was by the action of these that the rhyolites were decomposed, with the production of beds of alunite. Finally, in Post-Tertiary times, the softer sandstones were removed by denudation leaving the anticlinal arch of the harder alunite rock to form the summit of the Bullah Delah Mountain

*Photographed by E. F. Pittman.*

QUARRY IN ALUNITE DEPOSIT AUSTRALIAN ALUM COMPANY'S MINE, BULLAH DELAH MOUNTAIN.

The following Permo-carboniferous marine fossils have been identified by Mr. W. S. Dun amongst a number collected at Bullah Delah :—

| | |
|---|---|
| *Platyschisma oculum.* | *Chænomya* (?) *Etheridgei.* |
| *Aviculopecten tenuicollis.* | *Aphanaia.* |
| *Aviculopecten leniusculus.* | *Spirifera duodecimcostata.* |
| *Merismopteria macroptera.* | |

It may be mentioned that the marine sandstones in which these fossils occur have been intruded and cut across by a number of small veins or dykes (about half an inch in width) of a decomposed igneous rock ; it is probable that these are offshoots from the main dolerite dykes which intersect the series in an east and west direction.

*The Manufacture of Alum.*—The following is an outline of the process by which alum is manufactured from alunite. The mineral is ground, and then calcined in reverberatory furnaces, to dehydrate it and drive off part of the $SO_3$. It is next treated with a weak solution of sulphuric acid in lead-lined tanks, heated to boiling point by steam jets. The liquor is allowed to settle in the same vats, and the clear solution is run off into crystallising tanks, which are kept in constant agitation while cooling, the alum crystallising out, and sulphate of alumina remaining in solution. The residue in the vats is boiled again with water, and the solution run off again in the same way. The liquor containing sulphate of alumina is then returned to the vats, and sufficient of the calcined mineral added to completely neutralise any free acid. It is then heated to boiling point, and ebullition continued until partial *reversion* takes place, the reversion being accompanied by a precipitation of the hydrated ferric oxide.

The alum, after collection, is washed, and then refined in vats, similar to, but deeper than those originally employed, and the concentrated solution is run into roaching tuns, in which it is crystallised ; it is then broken up, and packed ready for the market.

The sulphate of alumina solution, after all the alum has been crystallised from it, is concentrated in small vats heated with steam coils, and the lower qualities of sulphate of alumina are formed by running the liquor on to lead tables, and breaking the solidified material into blocks ; the higher qualities (containing over seventeen per cent. of soluble alumina) being cast on copper trays. These higher qualities, which vary in colour from yellow to green in the slabs, are then ground in a disintegrator, and the material assumes a snow-white appearance.

It is, of course, feasible, by the addition of $K_2SO_4$, to convert the whole of the alumina contained in the stone into alum if desired, but the more profitable method of treatment, when the better classes of sulphate of alumina can be sold at standard prices, is to make only so much alum as there is sulphate of potash present in the stone to produce, and convert the rest of the alumina into soluble sulphate of alumina (of commerce).

Sulphur may be obtained by distilling the mineral in the presence of any reducing gas like coal-gas. Sulphuric acid may also be distilled from the mineral. Heating with carbonate of baryta produces aluminate of potash.

Production of Alunite.

| Year. | Quantity. | Value. |
|---|---|---|
| | tons. | £ |
| 1890 ... ... ... | 220·0 | 3,000 |
| 1891 ... ... ... | 704·0 | 1,888 |
| 1892 ... ... ... | 821·0 | 3,284 |
| 1893 ... ... ... | 1,284·0 | 5,136 |
| 1894 ... ... ... | 862·0 | 3,448 |
| 1895 ... ... ... | 832·0 | 3,328 |
| 1896 ... ... ... | 1 372·0 | 4,116 |
| 1897 ... ... ... | 724·5 | 2,172 |
| 1898 ... ... ... | 2,941·0 | 8,823 |
| 1899 ... ... ... | 921·0 | 2,763 |
| Totals ... ... | 10,681·5 | 37,958 |

# ASBESTOS.

Asbestos, or Amianthus, is a fibrous variety of the mineral hornblende, and is a practically anhydrous silicate of magnesia and lime, with a small proportion of iron and alumina. It is named after the Greek ἄσβεστος, *unquenchable* or *incombustible*, in allusion to the fact that this mineral, though having the appearance of vegetable fibre, will not burn. It can be carded, spun, and woven into cloth, which is flexible, a good non-conductor of heat, and perfectly indistructible by fire. The name amianthus, which is applied to the more silky varieties, is from the Greek, ἀμίαντος, *undefiled*, and was given to the mineral because the ancients were accustomed to weave it into napkins and other articles, which could be cleaned, when soiled, by being thrust into the fire. In colour it varies from white to green and brown.

The name asbestos is, however, now generally used in reference to the mineral chrysotile, or fibrous serpentine, which is of much greater commercial value than the original asbestos. It is more flexible and silky in texture, and is therefore more useful for manufacturing purposes than hornblende asbestos. It contains from 12 to 14 per cent. of chemically combined water, and no lime, whereas hornblende asbestos is almost anhydrous, but contains from 9 to 14 per cent. of lime. When fabrics made from chrysotile, however, are heated to redness, this water is driven off and the material becomes brittle.

Of late years there has been a rapidly increasing application of asbestos in the arts. Prior to 1878 the commercial supply of the mineral was all obtained from the Italian mines, where it occurs in very long fibres, but at the present time 85 per cent. of the World's production is supplied by Canada, the quality of the mineral found there being excellent, and the extent of the deposits being very great.

The Canadian asbestos occurs as veins of serpentine, of Cambrian, or Pre-Cambrian age, and is the variety known as chrysotile. It is much shorter in the fibre than the Italian, being seldom more than three inches in length, but it possesses great strength and flexibility, while it is as fine and brilliant as the purest silk. It has been ascertained that the asbestos which contains the highest percentage of combined water is always the most flexible.

According to Professor J. T. Donald (*Mineral Industry*), asbestos, mining in Canada is carried on in open quarries. "The rock is blasted, the portions containing asbestos are separated from barren rock, and go to the cobbing-house, where old men and boys knock off the long-fibred asbestos from the serpentine. The better qualities of asbestos separate readily from the enclosing rock, but in the case of narrow veins the separation of rock from fibre by hand is impracticable, and machinery such as rock-breakers, rolls, screens, and blowers have been introduced for this purpose."

The asbestos separated from the enclosing rock is divided into several grades, according to length of fibre, colour, and freedom from foreign matter. This usually amounts to only about one per cent. of the material, the balance being regarded as waste; but at the Danville Mine, in the province of Quebec, about 20 or 25 per cent. of commercial asbestos is recovered, and all the remaining material is utilised under the name of *Asbestic*, as it is found in this particular deposit to consist entirely of short fibrous chrysotile.

*Uses of Asbestos.*—Amongst the numerous articles manufactured from asbestos may be mentioned steam packing for flange joints and stuffing boxes, metallic packings, wick packings, wound cloth packing, millboard, millboard gaskets, impermeable sheet packing, piston-rod packing, "Salamander joints," asbestos cord, asbestos powder, woven sheeting, boiler and pipe coverings, furnace linings, asbestos fire-felt, insulating material, stove linings, asbestos washers, fireproof roofing, fireproof lining-felt for houses, fireproof flooring, fireproof curtains for theatres, filtering cloths, fireproof paint, insulators for electrical engineers, fireproof paper, gas shades, mail bags, fireproof ropes, belting, jeweller's moulds, stove mats, &c. A new use for asbestos is in the manufacture of what is known as asbestos leather. Very fine fibre is immersed in a solution of rubber, and the solvent of the latter is then allowed to evaporate, when the fibres are found to cohere perfectly. They are then pressed or rolled into any form desired, and the material is said to strongly resemble leather.

*Acid-resisting Asbestos.*—F. Schrader states that asbestos fabrics to resist acids, such as are required in the chemical industry, should be made of hornblende asbestos, in which the proportion of bases to silica is 1:1. Chrysotile asbestos, in which the proportion of bases to silica is 3:2, is attacked by very weak acids, like acetic acid, which dissolve the bases and leave almost pure silica without apparently destroying the fibrous condition. Boiling for four hours with dilute hydrochloric acid effects the same result. Chrysotile asbestos, on account of its fine and soft fibre, is particularly suitable for weaving and many technical applications, other than chemical; while hornblende asbestos, owing to its acid-resisting character, is capable of employment in chemical works. (*Chem. Ztg.*, 1897, p. 285.)

What was formerly regarded as waste material at the Danville Mine is now termed Asbestic, and it is manufactured into a very valuable wall plaster; in addition to being fireproof, this has the advantage of giving a surface as hard and smooth as marble, and is now largely used in the construction of commercial buildings in New York. Asbestic is also moulded into most artistic mural decorations, which are fireproof, and, at the same time, highly ornamental.

Production and value of Canadian asbestos from 1879 to 1899 inclusive. (*Mineral Industry.*)

| Year. | Tons (2,000 lb.) | Value in dollars. | Year. | Tons (2,000 lb.) | Value in dollars. | Year. | Tons (2,000 lb.) | Value in dollars. |
|---|---|---|---|---|---|---|---|---|
| | | $ | | | $ | | | $ |
| 1879 | 300 | 19,005 | 1886 | 3,458 | 206,251 | 1893 | 5,539 | 581,595 |
| 1880 | 380 | 24,700 | 1887 | 4,619 | 226,976 | 1894 | 7,649 | 535,430 |
| 1881 | 540 | 35,100 | 1888 | 4,404 | 255,007 | 1895 | 8,275 | 347,550 |
| 1882 | 818 | 52,650 | 1889 | 6,113 | 426,554 | 1896 | 10,380 | 311,400 |
| 1883 | 965 | 68,750 | 1890 | 9,860 | 1,260,240 | 1897 | 23,565 | 400,000 |
| 1884 | 1,141 | 75,097 | 1891 | 9,279 | 1,000,000 | 1898 | 23,015 | 500,000 |
| 1885 | 2,440 | 142,441 | 1892 | 7,431 | 909,878 | 1899 | 23,266 | 598,736 |

*Occurrence in New South Wales.*—Asbestos occurs in a number of localities in New South Wales, the deposits being in the form of veins in serpentine, and the fibres of the asbestos being generally arranged in a direction at right angles to the walls of the vein. In every instance observed the mineral appears to belong to the anhydrous or hornblendic variety, and, consequently, although the fibres are sometimes of considerable length, as at Gundagai (where they were over two feet long), and at Rockwell paddock, near Broken Hill, they do not possess either the strength, flexibility, or silky texture which is required in commercial asbestos, and which is so characteristic of the Canadian variety. It is doubtless owing to this fact that asbestos-mining in this Colony has not prospered, although the most sanguine hopes were entertained in regard to it a few years ago. It is probable that prospectors have been ignorant of the superior value of the short fibre chrysotile asbestos, and have confined their efforts to searching for the hornblende mineral, on account of its greater length of fibre. There is very little reason to doubt that if a systematic search were made chrysotile veins would be discovered in some of the numerous serpentine areas which are known to occur in New South Wales, and prospectors are, therefore, advised to examine the specimens of Canadian and Italian asbestos in the Geological Museum, with the object of enabling them to distinguish the valuable silky chrysotile from the comparatively worthless hornblende variety.

In the Geological Museum of the Department of Mines are specimens of asbestos from the following localities, viz., Red Hill, Rockwell Paddock, Broken Hill District, Gundagai, Burrowa, Springfield, Byng, Orange District, Rockley, and Tamworth District. In the sample from Gundagai the fibres are two feet five inches in length, but the mineral does not compare favourably with the long fibre asbestos from Italy; it possesses much less strength than the latter, and is more brittle. The Gundagai deposit was worked about twenty years ago by the Gundagai and Melbourne Asbestos Company, but the quality of the mineral exported was found to be unsatisfactory. An interesting fact connected with this mine was the discovery of gold in the fibrous serpentine, associated with the asbestos. A crushing of twenty tons of the auriferous stone yielded at the rate of two ounces of gold per ton. Much trouble was experienced in the treatment of the ore, owing to the sickening of the mercury in the mill. The gold ran out at a depth of ninety feet, and was last seen in the wall of the vein, but very little effort was made to prospect for its continuance, and the mine has been idle for years. Specimens of the fibrous serpentine, with flakes of gold as large as the finger nail adhering to it, can be seen in the Geological Museum.

Production and value of New South Wales Asbestos.

| Year. | Quantity. | Value. |
|---|---|---|
| | Tons. | £ |
| 1880 ... ... ... | 12·4 | 323 |
| 1881 ... ... ... | ......... | ......... |
| 1882 ... ... ... | 7·5 | 75 |
| 1883 ... ... ... | ......... | ......... |
| 1884 ... ... ... | ......... | ......... |
| 1885 ... ... ... | 6·0 | 90 |
| 1886–99 ... ... ... | ......... | ......... |
| Totals ... ... | 25·9 | £488 |

# DIATOMACEOUS EARTH.

Diatomaceous earth, or *Kieselguhr* as it is termed in Germany, is an exceedingly light, porous, white substance, which has been formed by the accumulation of the siliceous skeletons of micro-organisms termed Diatomaceæ, which are water plants (confervoid algæ). Each diatom consists of a cell enclosed in a siliceous carapace or shell. These diatoms are so minute that, according to an estimate by Dr. C. G. Ehrenberg, of Berlin, there are about 41,000,000,000 of them in a cubic inch of diatomaceous earth. The silica is in the colloidal condition, and was secreted by the organism from the water in which it lived. The geological features of the deposits of Diatomaceous earth in New South Wales appear to indicate that they are of lacustrine origin, and that the organisms lived in hot waters carrying silica in solution.

The name Tripolite is sometimes applied to Diatomaceous earth on account of the occurrence of deposits of this material at Tripoli, in Northern Africa.

When dry diatomaceous earth is so light that it will float readily on water, but when saturated it has a specific gravity of about 1·24.

The substance is unacted upon by heat or by ordinary acids, but is readily soluble in solutions of the alkalies. In consequence of its extremely porous nature, it readily absorbs liquids to the extent, it is stated, of four or five times its own weight.

*Uses of Diatomaceous Earth.*—On account of the exceedingly minute state of division of the grains of silica composing it, diatomaceous earth is peculiarly effective as an abrasive; its extreme porosity renders it very suitable for an absorbent, and as a non-conducting material; its low specific gravity, and its infusibility are qualities which are advantageous in the manufacture of light and refractory bricks; while its solubility in alkalies enables water glass to be easily prepared from it.

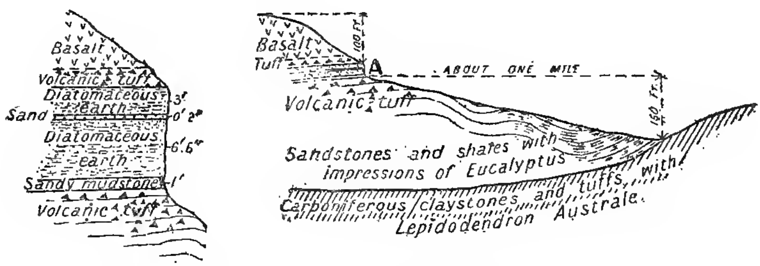
As an abrasive, or polishing powder, it is sometimes, when pure, used in its natural state, but if any foreign gritty matter be present this must be separated by levigation. By mixing the powdered earth with fat and alkali an effective soap is manufactured.

One of the principal uses of diatomaceous earth, or kieselguhr, is as an absorbent for nitro-glycerine in the manufacture of dynamite. For this purpose it is first calcined, ground between rolls, and then sifted. It is mixed with the nitro-glycerine by hand-kneading in troughs, and is then repeatedly passed through hair or metal sieves, to insure thorough incorporation. Various other materials have been used as absorbents instead of kieselguhr; but, so far, no substance has been found which answers the purpose so satisfactorily. Dynamite No. 1, or Giant Powder, as it is called in America, consists of 75 parts of nitro-glycerine, 25 parts of kieselguhr, and 0·5 of carbonate of soda. The mixture, which has the appearance of brown putty, is made up in cylindrical cartridges three and a half inches in length, which are wrapped in parchment paper.

Owing to its quality as a non-conductor of heat, diatomaceous earth has an extensive use as a covering for boilers and steam pipes, though in this direction it has to meet the competition of asbestos. Kieselguhr firebricks, which are said to be very useful in special cases where lightness and infusibility are required, have been manufactured in England.

*New South Wales Occurrences.*—The principal deposits of diatomaceous earth in New South Wales are those of Barraba, Cooma, Wyrallah (Richmond River), and the Warrumbungle Mountains.

The firstnamed occurs in the Nandewar Ranges, about twelve miles south-west of the township of Barraba. It appears to be of great extent, though the area occupied by it has not been surveyed. The deposit, which is probably of late Tertiary age and of lacustrine origin, apparently occupies a denuded hollow in the Carboniferous rocks, for the latter, containing impressions of the fossil plant *Lepidodendron australe*, are seen to outcrop around its margin.




SECTION OF TERTIARY STRATA ON PORTION 145, PARISH OF NORTH BARRABA, COUNTY OF DARLING.

The lowest beds of the Tertiary series consist of yellowish gray sandstones and shales, containing numerous impressions of *Eucalyptus* and other plant remains; above this is a volcanic tuff consisting of impure diatomaceous earth, with rounded pebbles, sanidine crystals, and fragments of pumice. In some places the tuff is very much impregnated with ferric oxide, forming a hard limonite. It is succeeded by a bed of yellowish-brown sandy mudstone about a foot in thickness, and resting

*Photographed by E. F. Pittman.*

BED OF DIATOMACEOUS EARTH, OVERLAID BY BASALT

Nandewar Ranges, 12 miles south-west of Barraba.

upon this is the bed of pure white diatomaceous earth, nine feet six inches in thickness, with a layer of two inches of coarse sand about three feet from the top. Another bed of volcanic tuff, containing numerous sanidine crystals, covers the kieselguhr, and is overlaid in turn by about 100 feet of basalt. The sedimentary beds undulate considerably, and as the lower members of the series are covered at the surface by thick deposits of soil, and can only be seen occasionally in the bed of the creek, it is difficult to estimate their respective thicknesses.

*Warrumbungle Mountains.*—This deposit of diatomaceous earth has been described by Professor David.* He states that in the neighbourhood of the deposit there are two formations represented:—(1.) The Permo-Carboniferous Coal Measures, and (2) trachyte lavas, dykes, and tuffs, with which last are associated the deposits of diatomaccous earth, and a seam of lignite. The trachytes have intruded the Permo-Carboniferous Coal Measures. "The latter consist of sandstones, quartzites, cherts containing well-preserved specimens of *Glossopteris*, finely laminated black shales, and at least one seam of coal, over six feet in thickness. The coal has been calcined by the trachyte dykes; and at the extreme right of the section beds of tracbyte tuff are seen resting, with strong unconformity, on the Permo-Carboniferous strata. . . . At several localities in the Warrumbungle Mountains the trachyte series is seen to overlie sandstones, which are almost certainly of Triassic age, and in this case the trachytes would be proved to be Triassic or Post-Triassic.

Professor David describes two distinct outcrops of the Diatomaceous earth deposit at the bottom of the valley of Wantialable Creek. The bed which has a thickness of from three feet to three feet nine inches, is interstratified with a series of trachyte tuffs and tuffaceous clays, and is overlaid by a sheet of trachyte at least twenty feet thick. The accompanying sketch sections are reproduced from Professor David's paper.

From the evidence supplied by the fossil plant, *Cinnamomum Leichhardtii*, and also from physical considerations, Professor David was of opinion that the age of these beds might be (provisionally) set down as early Eocene or late Cretaceous. In reference to the conditions under which the rocks were formed, he remarks as follows:—"I should like to emphasise the fact that hitherto all our Diatomaceous earths in New South Wales have been found in association with volcanic rocks, and I would venture to suggest that this association is far from accidental. The superheated water flowing from hot springs and from the lavas themselves during the trachytic eruptions would be certain to carry more or less silica in solution, and its high temperature, combined with its dissolved silica, would probably render it a very favourable medium for the development of Diatoms to the exclusion of most other kinds of plants. While some species of Diatoms flourish

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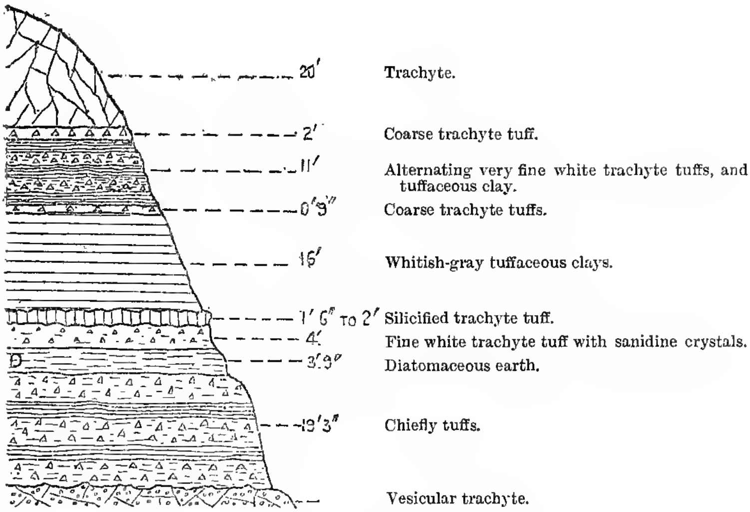
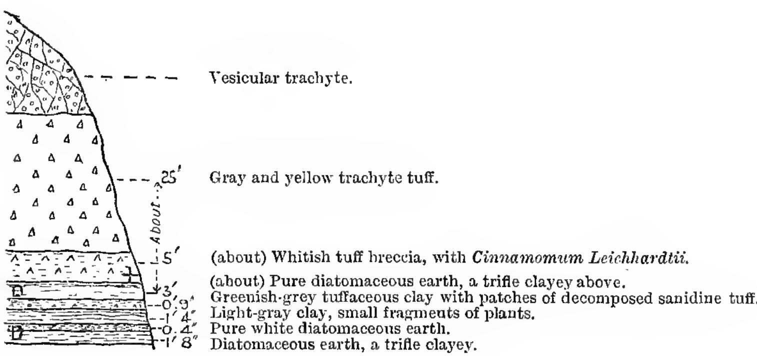
* *Procs. Lin. Soc. N.S.W.*, 1896, xxi, Pt. 2, pp. 261-268.




SECTION IN WANTIALABLE CREEK, NEAR TOORAWEENA, WARRUMBUNGLE MOUNTAINS,

Showing intercalation of diatomaceous earth in the Trachyte series.




SECTION IN WANTIALABLE CREEK, NEAR TOORAWEENA, WARRUMBUNGLE MOUNTAINS,

Showing diatomaceous earth in association with *Cinnamomum Leichhardtii.*

luxuriantly in the cold waters of the Antarctic Ocean, others may be found equally flourishing in the hot and highly mineralised waters of geysers. For example, Mr. H. N. Mosely has described the occurrence of Diatoms near the Boiling Springs at Furnas, St. Michael's, Azores, and their neighbourhood."

*Cooma.*—The deposit of Diatomaceous earth near Cooma has been described by Warden J. H. King in the following terms :—"It is situated about five miles from Cooma and one and a half from Bunyan Platform. It occurs in a hollow, partly surrounded by basalt hills. The surface is treeless and grassless, and the deposit is covered with about three inches of red earth and pieces of white quartz. The depth of the deposit is not known, as it has only been sunk on for sixteen feet. It is over a chain wide by six chains long exposed to view, and then occurs in the bottom of a gully about four feet deep. There is no doubt a large area of it, but deeply covered with soil."

*Wyrallah.*—The deposits of kieselguhr on the Richmond River although associated with the name of Wyrallah, probably occupy a considerable area in the neighbourhood of Lismore, as evidence of their occurrence has been observed at several localities. Like the Barraba and Cooma beds they are overlaid by a sheet of basalt, which is often vesicular in character. The distinguishing characteristic of the Wyrallah diatomaceous earth is the frequent occurrence in it of hard and stony material of a grayish white colour, and at the base of the deposit this passes into a band of common opal, about one foot in thickness. As will be seen by the appended analyses, the silica contents are higher than in average samples of kieselguhr, but the value of much of the material has been destroyed by the loss of its porosity. It is evident that it has been subjected to hydrothermal action, whereby secondary silica has been deposited and a stony structure induced. Numerous impressions of fossil plants occur in the Wyrallah diatomaceous earth, and the late Baron von Mueller has described *Liversidgea oxyspora,* and a specis of *Pteris.*

In a paper entitled "The Diatomaceous Earth Deposits of New South Wales,"* by Messrs. G. W. Card and W. S. Dun, the authors have named the Diatoms occurring in the principal known localities. The Warrumbungle Mountains earth was found to consist mainly of *Melosira* and *Spongilla* spicules, and rare evidences of a naviculoid genus were also observed. The Barraba earth was found to contain *Melosira* and *Spongilla* spicules in abundance. A specimen from Newbridge contained, in addition, a Naviculoid genus. The richest earth (in regard to variety of Diatoms), was one said to come from Paddy's River, Shoalhaven; in this were recognised the common species of *Melosira*, and, in addition, *M. Jurgensi*, *Navicula*, *Cymbella*, and *Spongilla.*

* Records Geol, Survey N. S. Wales, 1897, v, pt. 3, pp. 128-148.

Composition of New South Wales Diatomaceous Earth.

The following analyses were made by the Analyst to the Department of Mines :—

| | Barraba, 3 miles from. | Barraba. | Barraba. | Glen Innes, 32 miles from. | Richmond River (Wyrallah). | Richmond River (Wyrallah). | Cooma. | Cooma. | Cooma. | Warrumbungle Mountains. | Warrumbungle Mountains. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Silica ... ... ... ... | 71·62 **80·67** | 71·13 **81·54** | 80·56 **92·59** | 71·53 **81·85** | 86·01 **96·81** | 90·94 **96·27** ferrous oxide 0·33 | 81·64 **91·83** | 83·30 **94·22** | 80·94 **90·79** | 82·62 **93·07** | 72·94 **81·68** |
| Ferric Oxide . ... ... | 14·07 | 0·91 | 1·77 | trace | 2·83 | 0·49 | 0·40 | 0·36 | 1·23 | 5·20 | 0·87 |
| Alumina ... ... ... | | 13·06 | 4·15 | 14·36 | | 2·38 | 3·20 | 3·84 | 4·61 | | 4·57 |
| Calcium Carbonate ... ... | 1·43 | lime 0·31 | 0·31 | 0·82 | trace | ... | 1·50 | lime 0·30 | 0·86 | 0·95 | 9·53 |
| Magnesium Carbonate ... | 1·66 | magnesia 0·87 | 0·21 | 0·68 | trace | trace | 2·16 | magnesia 0·36 | 0·45 | trace | 0·70 magnesia 0·69 |
| Sodium Chloride ... ... | ...... | carbon dioxide 0·95 | ...... | ...... | ...... | 0·32 | ... | 0·25 | 1·06 | ... | ...... |
| Combined Water .. ... | 4·03 | 5·67 | 12·84 | 6·14 | 5·96 | 2·79 | 3·77 | 5·84 | 2·99 | 3·49 | 3·08 |
| Moisture at 100° C. ... ... | 7·30 with organic matter | 7·33 | alkalies and loss 0·16 | 6·50 | 5·36 | 2·69 | 7·18 | 5·40 | 8·07 | 7·70 | 7·88 |
| | 100·01 | 100·23 | 100·00 | 100·03 | 100·16 | 99·94 | 99·85 | 99·65 | 100·21 | 99·96 | 100·26 |

The figures in black type represent the percentages of Silica in the diatomaceous earth after calcination.

*Production of Diatomaceous Earth.*—Up to the present time little or no use has been made of the kieselguhr occurring in this country. Small quantities from the Wyrallah deposit have been sent to London for experimental purposes, and in 1896 some 676 bushels were sent away, and realised at the rate of 3s. 6d. per bushel bagged and delivered in Sydney. A few tons have also been raised, for experimental purposes, from the Cooma deposit, but no regular trade has as yet been established

# FIRE-CLAY AND POTTER'S CLAY.

Clays of a sufficiently refractory character to be suitable for the manufacture of fire-bricks, &c., are of fairly frequent occurrence in New South Wales, though as yet there has not been a very large trade established in colonial fire-bricks; this is probably owing to the fact that when smelting works are started in remote districts it generally happens that a clay, sufficiently good for furnace linings, can be obtained locally, and in this way the expense of carriage is avoided.

Fire-clays of good quality are found in the Wianamatta shales in the County of Cumberland, and also in the Permo-Carboniferous Coal Measures. The following is a list of a number of clays which have been analysed or tested in the Laboratory of the Department of Mines:—

| Locality. | Moisture at 100° C. | Combined Water. | $SiO_2$. | $Al_2O_3$. | $Fe_2O_3$. | FeO. | MnO. | CaO. | MgO. | $Na_2O$. | $K_2O$. | $P_2O_5$. | $SO_3$. | Organic Matter. | $T_1O_2$. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blayney (King's Plains). | ·50 | 3·56 | 74·40 | 16·88 | 1·11 | ·11 | tracc | .. | ·29 | ·03 | 2·79 | trace | .. | .. | .. |
| Bulli .. .. | 2·21 | 6·06 | 55·90 | 17·17 | 5·73 | .. | trace | 1·80 | 2·12 | ·57 | 1·91 | trace | .. | 6·28 | trace |
| ,, .. .. | 1·15 | 4·06 | 61·30 | 19·55 | 2·45 | .. | .. | ·25 | 2·73 | .. | 2·69 | . | .. | 6·39 | .. |
| ,, .. .. | 1·94 | 1·60 | 59·92 | 26·26 | 2·03 | .. | trace | ·13 | ·23 | trace | 1·99 | .. | .. | 5·55 | .. |
| ,, .. .. | 1·70 | 3·57 | 60·10 | 19·76 | 1·59 | .. | .. | ·50 | 1·11 | .. | 2·14 | .. | .. | 10·03 | .. |
| Caloola Creek near Orange. | ·35 | 3·13 | 79·28 | 14·80 | ·54 | .. | .. | ·28 | ·25 | 1·37 | | .. | .. | .. | .. |
| Capertee .. .. | 7·50 | | 62·05 | 28·00 | .. | trac | .. | ·30 | ·47 | 1·68 | | .. | .. | .. | .. |
| Cobar (*a*) .. .. | 1·75 | 4·54 | 65·82 | 20·74 | 1·45 | .. | trace | ·10 | ·97 | ·07 | 4·58 | trace | ·19 | .. | .. |
| Cook's River (*b*) .. | 1·47 | 7·29 | 70·98 | 18·12 | ·25 | .. | trace | .. | ·18 | 1·71 | | .. | .. | trace | .. |
| Coraki Colliery .. | 2·45 | 4·86 | 67·64 | 19·18 | 1·11 | ·28 | | ·52 | ·79 | ·57 | 2·98 | trace | .. | .. | .. |
| Cumberland, (*c*).. county of. | 1·45 | 3·44 | 80·79 | 13·20 | ·86 | | .. | .15 | trace | ·11 | | .. | .. | .. | .. |
| Don Dorrigo .. | 2·96 | 4·83 | 71·13 | 17·15 | 2·02 | | | trace | ·85 | ·93 | ·35 | ·05 | trace | .. | .. |
| ,, ,, (*d*).. (Second sample) | | .. | .. | .. | | .. | | .. | .. | .. | .. | .. | .. | .. | .. |
| Forster (*e*) .. | 2·88 | 5·95 | 70·57 | 16·27 | 1·07 | .. | .. | ·13 | ·38 | ·27 | 2·20 | .. | ·41 | .. | .. |
| Heathcote .. | 4·57 | | 74·48 | 18·83 | ·39 | .. | trace | .. | ·72 | .. | 1·58 | tracc | trace | .. | trace |
| ,, .. .. | 1·04 | 3·33 | 78·31 | 15·29 | ·74 | .. | trace | trace | trace | 1·29 | | trace | .. | .. | .. |
| ,, .. .. | 1·76 | 5·56 | 72·44 | 16·70 | ·28 | 1·00 | trace | ·45 | ·36 | 1·45 | | trace | trace | .. | .. |
| Illawarra District | 1·42 | 4·25 | 76·80 | 13·97 | 1·58 | .. | trace | trace | ·61 | tracc | 1·54 | trace | trace | .. | trace |
| King's Plains .. (*vide Blayney*) | .. | .. | .. | . | .. | .. | .. | .. | .. | | .. | .. | .. | .. | .. |
| Leconfield (Branxton). | 3·15 | 6·98 | 60·10 | 24·88 | 1·27 | .. | .. | ·36 | 1·18 | ·08 | 2·49 | trace | trace | .. | tracc |
| Macleay River .. | 2·37 | 6·07 | 65·17 | 21·89 | ·19 | .. | .. | ·50 | 1·03 | 1·16 | 2·02 | .. | trace | .. | .. |
| Merimbula .. | 8·21 | | 73·35 | 14·23 | 1·02 | .. | .. | tracc | ·65 | 1·30 | ·79 | .. | trace | .. | trace |
| ,, .. | 2·04 | 7·17 | 68·73 | 19·00 | 1·85 | .. | .. | ·20 | ·27 | ·74 | | .. | .. | .. | trace |
| Molong, 3 miles west of (*f*). | .. | .. | .. | .. | | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |

| Locality. | Moisture at 100° C. | Combined Water. | $SiO_2$. | $Al_2O_3$. | $Fe_2O_3$. | FeO. | MnO. | CaO. | MgO. | $Na_2O$. | $K_2O$. | $P_2O_5$. | $SO_3$. | Organic Matter. | $TiO_2$. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mount Hope .. | ·61 | 7·33 | 63·00 | 25·75 | 1·24 | .. | trace | ·40 | trace | ·14 | 1·69 | trace | ·10 | .. | .. |
| Mount Pleasant Colliery. | 1·48 | 4·61 | 68·28 | 21·29 | ·87 | .. | | ·30 | ·70 | ·31 | 1·86 | .. | .. | trace | trace |
| Mudgee .. .. | ·34 | 3·71 | 73·28 | 18·00 | ·54 | .. | | ·37 | ·33 | 3·73 | ·07 | .. | .. | trace | .. |
| Narrabeen, sandy clay (*g*). | .. | .. | .. | | .. | .. | | .. | .. | .. | .. | .. | .. | .. | .. |
| Brick made from above. | . | .. | 89·45 | 10·40 | trace | .. | .. | trace | trace | ·36 | ·32 | | .. | .. | trace |
| Parramatta, 2 m'l's from (*h*). | 1·05 | 2·35 | 85·35 | 8·81 | ·79 | .. | trace | | ·43 | trace | 1·48 | trace | .. | .. | trace |
| Port Stephens .. | 1·84 | 4·36 | 74·57 | 16·47 | 1·18 | .. | trace | ·17 | trace | .. | 1.03 | .. | trace | .. | . |
| Richmond River (*i*) | 2·60 | 2·38 | 65·95 | 18·85 | 3·33 | .. | .. | trace | ·97 | ·83 | 2·02 | ·09 | trace | 2·96 | .. |
| ,, ,, (*j*) | 1·56 | 4·38 | 67·28 | 20·07 | 1·03 | .. | .. | ·60 | 1·19 | ·62 | 3·08 | .. | .. | trace | trace |
| ,, ,, (*k*) | 1·78 | 6·30 | 65·06 | 20·90 | 1·24 | .. | trace | ·66 | ·76 | ·17 | 3·21 | trace | trace | ·10 | .. |
| Rouse Hill, near Parramatta (*l*). | .. | .. | .. | .. | .. | .. | .. | .. | | .. | .. | .. | | .. | |
| St. Leonards .. | 2·29 | 5·96 | 64·89 | 22·66 | 1·60 | .. | .. | ·46 | ·62 | ·02 | 1·92 | trace | | trace | trace |
| Swan Bay. *vide Richmond River* | . | .. | .. | | . | .. | .. | .. | .. | .. | | .. | | .. | .. |
| Sydney, near (*m*) | | | | .. | .. | . | .. | .. | | .. | | .. | | .. | .. |
| Tempe (*n*) .. | .. | .. | .. | .. | .. | .. | .. | .. | . | .. | | .. | .. | .. | .. |
| Towrang, near Goulburn (*o*) | 4·78 | | 80·88 | 13·86 | ·51 | .. | .. | ·15 | trace | trace | trace | .. | .. | .. | .. |
| Towrang, near Goulburn (*p*) | ·82 | 3·30 | 71·90 | 16·15 | 1·45 | .. | trace | trace | ·50 | ·57 | 4·77 | trace | | .. | .. |
| Towrang, near Goulburn (*q*) | ·60 | 4·10 | 75·08 | 15·17 | 1·61 | .. | trace | ·35 | ·10 | 1·20 | 1·32 | ·03 | 0·6 | .. | .. |
| Towrang, near Goulburn (*r*) | ·67 | 2·97 | 79·54 | 12·53 | 1·26 | .. | trace | ·34 | ·61 | ·50 | 1·82 | ·02 | ·04 | .. | .. |
| Tumbarumba (*s*) .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | . | . | .. | .. | .. |
| Waratah .. .. | 2·88 | 6·86 | 65·40 | 19·01 | 5·36 | .. | trace | 0·5 | ·07 | ·29 | ·35 | .. | ·13 | | .. |
| Wollongong .. | 1·87 | 8·13 | 53·80 | 21·77 | ·37 | ·14 | trace | 1·17 | 12·89 | trace | ·40 | .. | .. | .. | .. |
| Woonoona (*t*) .. | 2·05 | 7·39 | 58·80 | 23·33 | 1·10 | .. | trace | 1·06 | ·65 | ·15 | 2·09 | ·07 | ·11 | 3·71 | .. |

*Remarks by the Analyst.*

(*a*) White clay used by the Cobar Copper Company for the manufacture of fire-bricks; it is first mixed with sandstone and quartz.

(*b*) Very plastic dark-coloured clay.

(*c*) This is an excellent description of fire-clay, and can be classed as equal, if not superior in quality, to the English imported article. It should prove useful for the manufacture of fire-bricks, tiles, &c., and perhaps might be utilised for the manufacture of crucibles, &c. The percentage of silica is higher than that usually present in the English fire-clays.

(*d*) White clay. A portion of the clay was moulded into the shape of a small brick; also, a second brick was made, with the addition of half its weight of sand. After careful drying they were placed in a covered crucible, and submitted to the highest heat obtainable in a coke assay furnace for some four hours. The bricks, on cooling, showed no fusion had taken place, the sharp edges and original shape being retained.

(*e*) Bricks made from this clay and submitted to a high heat in the coke assay furnace showed no fusion, the sharp edges being retained. The bricks appeared to be of excellent quality.

(*f*) Black fire-clay. A small brick was made of the sample, and well heated in a coke furnace. The brick proved to be highly refractory, but was distorted and much cracked.

(*g*) Carbonaceous sandy clay. The clay was finely ground, damped with water, and fashioned into two small bricks with sharp edges, which, after drying, were submitted to a severe heat in the assay furnace. The bricks were solid, and burnt white, the sharp edges being retained. The clay is suitable for the manufacture of a good description of fire-brick, and can probably be utilised for the manufacture of hearthstones.

(*h*) Wianamatta shale, with plant impressions.

(*i*) Richmond River (Aberdare Colliery, Swan Bay). Bricks made of this clay were of reddish colour, due to the iron oxide present; the sharp edges were retained after burning, but in one or two places slight fusion had taken place.

(*j*) Richmond River (Aberdare Colliery, Swan Bay). Yielded excellent bricks, the sharp edges being retained, and no signs of fusion being observable.

The deposits of clay in the Parish of Towrang, near Goulburn (*vide* notes *o*, *p*, *q*, *r*, above), have been examined by Mr. J. B. Jaquet, Geological Surveyor, who reported that they consist of the upper and weathered portions of a series of highly inclined beds of shaly slates of Siluro-Devonian age. Where these rocks are exposed at the surface the soft clays resulting from their decomposition are denuded rapidly away, but where they are protected by overlying alluvial deposits, as is the case under the flats which extend along Boxer's Creek, the clays remain *in situ*. Planes of parting which represent the original bedding and cleavage planes of the parent rock can be distinguished in the clays. Mr. Jaquet states that the deposits are of enormous extent, and in the event of the clays being utilised in the manfacture of firebricks or pottery there need be no apprehension as to the supply of raw material becoming exhausted.

*Potter's Clay, &c.*—Kaolin or China clay, which is derived from the decomposition of the felspars in granite, and consists of hydrous silicate

(*k*) Two bricks were made up of this clay—one with the clay only, and the other with half its weight of clean sand. After being carefully dried, they were burnt at a high temperature in the coke assay furnace. The first was bulged out at the end, and rendered porous; no fusion had taken place, the sharp edges being retained. The other stood the test fairly well, but the clay probably contains too much alkalies for the manufacture of a first-class fire-brick.

(*l*) Kaolinised felspathic grit. Bricks made from this material, with and without the addition of 50 per cent. of silica, showed no sign of fusion after being subjected to a severe heat in a coke assay furnace. This material would appear to be suitable for the manufacture of a fair class of fire-brick.

(*m*) Four samples of clay shale from near Sydney. These samples were kneaded with water, and fashioned into small prismatic pieces with sharp edges, thoroughly dried, and heated in a covered crucible for some hours in a powerful wind furnace fed with coke.

Nos. 1 and 2 :—These samples were submitted to the above test in a wind furnace for some hours, and were found neither to have fused nor altered in appearance, the edges remaining sharp. They are a fine description of clay, being free from grit, and would be useful for the manufacture of pottery, fire-tiles, etc.

No. 3 :—This sample contained a small quantity of organic matter (leaves, etc.). On kneading some, making it up into a small brick, and calcining it, it was found to be spotted over with small holes, due to the gases given off from the organic matter in the sample. The sides were sharp, and in other respects this is a good fire-clay, and useful for many purposes.

No. 4 :—This is a coarser description of clay, and has more sand in its composition. It is a good fire-clay, and stood the test well ; it would make excellent fire-bricks.

(*n*) Wolli Creek, Tempe, from 9 to 28 feet from the surface. On carefully drying this brick, and submitting it to a severe heat in the coke assay furnace (the brick being protected from the coke by placing it in a crucible), it split into small pieces. The sharp edges were retained, and no fusion had taken place.

(*o*) White felspathic sandstone rock, with slight stains of red oxide of iron. This is an excellent description of fire-clay, and, from the large percentage of silica present, should prove very refractory.

(*p*) White clay. The bricks stood the test well, showing no signs of fusion.

(*q*) Kaolin from Parish of Towrang, near Goulburn. Two small bricks were made of clay alone, and two with the addition of 50 per cent. of clean sand. The bricks were dried for some days, placed in a muffle furnace and thoroughly burned ; they were then put into a luted crucible in the coke furnace, and submitted to a severe heat for some hours. The bricks after this treatment showed no signs of fusion having taken place, the sharp edges being retained. The material appears to be useful for the manufacture of a good refractory brick. The percentage of alkali, however, is too high for a first-class article.

(*r*) Apparently a bleached shale. Two small bricks of clay alone, and two with the addition of 50 per cent. of clean sand were made. They were dried, burned in a muffle furnace, then placed in a luted crucible and submitted to a severe heat for some hours in a coke furnace. The bricks, after this treatment showed no signs of fusion, their sharp edges being retained. The material appears to be useful for the manufacture of a good refractory brick ; the percentage of alkali is, however, too high for a first-class article.

(*s*) Clay from Cherry Hill, Tumbarumba. A small brick was made of this clay, and was carefully dried and burned at a high heat in the coke assay furnace. The brick retained its sharp edges, and showed no signs of fusion.

(*t*) Bricks made of this clay, after heating at a severe temperature, showed no sign of fusion, their sharp edges being retained.

of alumina, has been found in many granitic districts, such as Bathurst, Gulgong, Uralla, Tichbourne, near Parkes, &c.; up to the present time, however, kaolin-mining has not been established as a regular industry.

In his "Geology of the Vegetable Creek Tin-mining Field." Professor David mentions that extensive beds of grayish white pipeclay are interstratified with the Tertiary sand and gravel of the deep *leads*. The beds are from ten to twenty feet thick in places, are very free from grit, and occasionally, as at the Graveyard and Rose Valley, are nearly white, approaching China clays.

The following is a list of analyses of clays, suitable for the manufacture of pottery, which have been received in the Department of Mines from different parts of New South Wales.

*Analyses of Potters' Clays.*

| Locality. | Moisture at 100° C. | Combined Water. | $SiO_2$. | $Al_2O_3$. | $Fe_2O_3$. | FeO. | MnO. | CaO. | MgO. | $Na_2O$. | $K_2O$. | $P_2O_5$. | $SO_3$. | Organic matter. | $TiO_2$. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Barringun.. .. | 6·07 | ·05 | 77·11 | 14·26 | | .. | .. | ·25 | ·71 | 1·55 | | .. | .. | .. | trace |
| Burrowa .. .. | 1·10 | 6·15 | 59·70 | 27·87 | ·68 | ·50 | .. | ·40 | 1·33 | trace | 2·89 | trace | .. | .. | ... |
| Carlingford .. | 2·61 | 10·66 | 43·94 | 34·17 | ·80 | | .. | trace | ·34 | ·004 | 1·36 | .. | .. | trace | 5·81 |
| Casino .. .. | 7·74 | 7·41 | 49·72 | 27·62 | 1·80 | | trace | 2·46 | 1·65 | ·60 | 1·30 | trace | .. | .. | .. |
| Dalton .. .. | 1·94 | 6·64 | 58·51 | 27·86 | 1·30 | | .. | ·24 | ·61 | ·29 | 2·29 | .. | .. | .. | .. |
| Dubho, 30 miles south-east of. | 1·09 | 13·38 | 45·27 | 39·05 | 1·08 | .. | .. | | ·22 | .. | ·32 | trace | .. | .. | trace |
| Dundible Creek, Tweed River. | ·90 | 4·64 | 70·64 | 20·14 | ·80 | .. | .. | ·24 | ·10 | 1·13 | 1·22 | .. | .. | .. | .. |
| Hastings River .. | ·49 | | 63·03 | 31·75 | trace | .. | .. | .. | 1·12 | ·86 | 1·66 | 31 | trace | | .. |
| Hawkesbury District. | 8·22 | 3·82 | 52·96 | 25·45 | 2·42 | .. | trace | 1·18 | 1·52 | 2·02 | 2·23 | trace | .. | | trace |
| Kogarah .. .. | 3·44 | 11·67 | 48·65 | 33·25 | . | .. | .. | trace | ·93 | 1·51 | ·35 | .. | .. | .. | trace |
| Larras Lake .. | ·71 | 3·89 | 71·16 | 17·47 | 1·55 | .. | trace | 1·65 | ·23 | trace | 3·28 | trace | trace | | .. |
| Lithgow .. | 1·88 | 11·27 | 46·41 | 39·08 | ·40 | .. | trace | trace | trace | | ·68 | .. | trace | | .. |
| Manning River .. | 4·27 | | 70·23 | 19·27 | 1·54 | .. | trace | trace | ·23 | trace | 4·50 | trace | trace | .. | trace |
| Milton .. | 6·58 | 11·35 | 45·79 | 34·54 | ·90 | .. | .. | ·31 | trace | trace | ·65 | trace | .. | trace | .. |
| Mudgee .. | ·96 | 6·26 | 52·00 | 31·20 | 1·70 | .. | trace | ·50 | 2·34 | trace | 5·33 | trace | trace | | .. |
| ,, | ·32 | 3·82 | 69·40 | 19·33 | 1·31 | .. | .. | ·59 | 1·23 | ·52 | 3·73 | .. | .. | . | .. |
| ,, 10 miles from. | 4·24 | | 69·50 | 21·63 | trace | .. | .. | ·20 | ·68 | ·43 | 3·54 | .. | .. | .. | .. |
| Murrurundi .. | 15·04 | 8·21 | 45·09 | 15·76 | ·48 | .. | trace | 1·65 | 13·61 | trace | trace | .. | .. | .. | .. |
| Newbridge .. | ·20 | 4·90 | 73·40 | 18·73 | ·07 | .. | .. | ·25 | trace | trace | [illegible]·23 | .. | .. | .. | trace |
| Parkes, 6 miles east of Flagstone Ck. | 7·65 | 4·62 | 50·68 | 18·71 | 12·51 | .. | trace | ·52 | 2·28 | 1·34 | | trace | 1·69 | | .. |
| Peak Hill .. .. | 1·19 | 6·00 | 69·82 | 20·66 | 0·41 | .. | .. | .. | ·30 | ·04 | 1·75 | .. | .. | | .. |
| Port Stephens .. | 10·09 | 5·98 | 50·16 | 23·00 | 4·92 | .. | trace | 1·20 | ·75 | ·52 | 3·40 | trace | .. | | .. |
| ,, .. | 1·84 | 4·36 | 74·57 | 16·47 | 1·18 | .. | trace | ·17 | trace | .. | 1·03 | .. | trace | .. | .. |
| Tumut (Shaking Bog). | 6·10 | 10·19 | 44·46 | 37·85 | trace | .. | | ·22 | trace | 1·18 | | .. | | | .. |
| Ulladulla .. .. | 2·16 | 11·95 | 46·61 | 37·64 | . | .. | .. | ·30 | ·14 | trace | 1·28 | .. | .. | | .. |
| Wyanglo, parish of, Tumut District. | 6·70 | 11·70 | 41·24 | 35·10 | ·68 | .. | trace | 1·80 | 1·33 | | 1·96 | .. | .. | | .. |

In the County of Cumberland there is a considerable number of works where the manufacture of bricks, tiles, earthenware pipes, &c., is carried on, the material used being the clays and shales of the Wianamatta beds which overlie the Hawkesbury sandstones. As already stated, some of these shales are sufficiently refractory to form good fire-bricks.

*The Lithgow Valley Pottery* is the most extensive establishment of its kind in New South Wales. The works cover a large area of ground, and the necessary shales and fire-clay are obtained from a quarry in the Upper Coal Measures alongside. Prior to 1896 many kinds of fancy pottery were manufactured in addition to bricks, fire-bricks, tiles, and earthenware pipes, but since that date only the last-named articles have been produced. There can be very little doubt, however, that when the federal tariff is in operation this important industry will not only be revived, but greatly enlarged.

*Fuller's Earth.*—A deposit of Fuller's Earth, which is said to be of considerable dimensions, occurs in the Permo-Carboniferous Coal Measures at Wingen. The material has been described by Mr. G. W. Card,* Curator, and an analysis made by Mr. J. C. H. Mingaye.

The composition is as follows:—

| | |
|---|---|
| Moisture ... ... ... .. ... | 13·73 |
| Combined water ... ... ... ... | 6·45 |
| Silica ... ... ... ... ... | 50·61 |
| Alumina ... ... ... ... ... | 19·35 |
| Ferric oxide ... ... ... ... | 3·55 |
| Lime ... ... ... ... ... | 1·37 |
| Magnesia ... ... ... ... ... | 3·24 |
| Potash ... ... ... ... ... | ·92 |
| Soda ... ... ... ... ... | ·47 |
| Phosphoric anhydride ... ... ... | trace. |
| | 99·69 |

Production of Fire-clay.

| Year. | Quantity. | Value. |
|---|---|---|
| | Tons. | £ |
| 1891 ... ... ... ... | 16·80 | 55 |
| 1892 ... ... ... ... | 35·00 | 80 |
| 1893 ... ... ... ... | 21·00 | 46 |
| 1894 ... ... ... ... | 24·00 | 60 |
| 1895 ... ... ... ... | 19·50 | 55 |
| 1896 ... ... ... ... | 34·15 | 69 |
| 1897 ... ... ... ... | ........ | ......... |
| 1898 ... ... ... ... | 14·35 | 32 |
| 1899 ... ... ... ... | 26·95 | 66 |
| Totals ... ... ... | 191·75 | 463 |

* Records Geol. Survey N. S. Wales, 1894, IV. pt. 1, pp. 30–32.

*Photographed by E. F. Pittman.*

THE LITHGOW VALLEY POTTERY CO.'S WORKS, LITHGOW.

# OCHRE.

Very large deposits of ochreous clays, suitable for the preparation of pigments and kalsomines, occur in many parts of New South Wales, and several attempts have been made to establish an ochre mining industry, but hitherto without much success. There were at one time two establishments near Sydney where the manufacture of paints from these clays was carried on; these were the Longnose Point Paint Works, at Balmain, and the Gordon Emery and Colour Co. (Limited), at Forest Lodge. The latter Company started on an extensive scale, and produced a fine series of delicate pigments, but the enterprise was found to be unremunerative, and the works had to be closed. In view of the price of labour in Australia as compared with Europe, the manufacture of paints of this description could, perhaps, hardly be expected to succeed here under a policy of free-trade, but with the advent of federation and the imposition of duties upon importations, there is every reason to hope that a large industry will be established in ochre-mining.

The ochres occur in horizontal or undulating beds of considerable thickness in the following localities, viz.:—Kerr's Creek, Orange district; Larras Lake, and other places around Molong; from four to seventeen miles to the east of Dubbo; near Mudgee; Wingello; Barber's Creek; Myall Lake, etc. They are of Tertiary age and are sometimes overlaid by basalt. The clays or ochres vary much in colour, being white, buff, yellow, various shades of red, and purple. Their general composition is shown by the following analysis (made by Mr. J. C. H. Mingaye) of a sample of yellow ochre from Dubbo:—

| | |
|---|---|
| Moisture ... ... ... .. ... | 1·64 |
| Combined water ... ... ... .. ... | 8·99 |
| Silica ... ... ... ... ... ... ... | 43·38 |
| Alumina ... ... ... ... ... ... | 11·05 |
| Ferric oxide ... ... ... ... ... ... | 34·81 |
| Ferrous oxide ... ... ... ... ... | trace. |
| Manganous oxide ... ... ... ... ... | trace. |
| Lime ... ... ... ... ... ... ... | trace. |
| Magnesia ... ... ... ... ... ... | trace. |
| Phosphoric anhydride ... ... ... ... | ·21 |
| Sulphuric anhydride ... ... ... ... | ·12 |
| | 100·20 |

A large number of analyses of different samples has been made, and, as might be expected the proportion of ferric oxide is found to be very variable; thus another sample of ochre from Dubbo contained 65 per cent., while one from Wingello yielded 68 per cent., and an umber from Barber's Creek, gave 43·93 per cent. No distinct relation can, however, be traced between the proportion of ferric oxide and the colour of the ochre, and it is probable that the latter depends to a considerable extent on the amount of hydration of the oxide of iron.

# MARBLE.

New South Wales is richly endowed with beds of marble of many varieties of colour, and of highly ornamental markings; much of the marble is eminently suitable for decorative work, and it is a surprising fact that the attention of builders has only recently been attracted to them.

In the Geological Museum there is a fine collection of polished specimens of these stones, and in the following list the descriptions have been supplied by Mr. W. H. Gilding, a skilled lapidary attached to the Department of Mines:—

List of specimens of Polished Marble in the Geological Museum.

| Locality. | Description. |
|---|---|
| Bibbenluke ... ... | Black and white fossil marble; similar to Sussex marble. |
| Bungonia ... ... ... | Dove-gray; an excellent marble. |
| Caloola, Newbridge ... | White; used in the floor of the University. |
| Carwell, Rylstone ... | Small pieces only; black, equal to Derby. It takes a good polish, and is the best black in New South Wales. |
| Cow Flat ... ... ... | Poor white; suitable for out-door steps; used for flooring in certain public offices. |
| Cudal ... ... ... | Black; although not so good in colour, it polishes as well as Derby; suitable for tiles. |
| Fernbrook, Bathurst ... | A great variety of excellent marble. |
| | Black and gold. |
| | Mottled red (very good). |
| | Prettily veined, "rouge royale." |
| | Red, equal to Devonshire. |
| | Dark gray and pink—coral. |
| | Gray and pink with silver veins. |
| | Wavy red, suitable for reredos or inlaid work. |
| | Mottled with jasper-red and brown spots. |
| Kempsey ... ... ... | Crinoidal marble, pink and brown. |
| Marulan ... ... ... | Mottled gray, white and gold. Executive Council Chambers mantels. |
| | Dark gray, equal to Devonshire gray; suitable for large work, panels, columns, &c. |
| | Spotted gray. |
| | Dove gray in different shades; used for flooring in certain public offices. |
| | "Sienna." |
| Molong ... ... ... | A great variety of excellent marble. |
| | Devonshire red. |
| | (*Gamboola.*) Red and gold with gray spots; resembles Derbyshire red. |
| | (*Boree.*) Green, equal to Irish green. |
| | Dark gray with silver streaks, very effective. |
| | (*Boree.*) Red, fossil. |

| Locality. | Description. |
|---|---|
| Molong ... ... ... | Greenish gray; good. |
| | Dark dove, wavy; easily polished; suitable for bases. |
| | Chocolate; fossil. |
| | Dark gray and gold. |
| | Pink and brown, with white veins and spots; a superb marble. |
| | Yellow and gold; takes a splendid polish; very good. |
| Moonbi ... ... ... | Great variety in colour and marking, including a rare green; inferior in polishing capacity. |
| Mudgee ... ... ... | A number of magnificent marbles. |
| | Beautiful white "Australian-Sicilian"; this works quite as well as Sicilian. |
| | (*Sawpit.*) Mottled chocolate in different shades; sometimes mottled with pink and green. |
| | Mottled gray. |
| | (*Buckeroo.*) Light gray, mottled with dark gray, sometimes streaky. |
| | Pink and gold. |
| Orange ... ... ... | Streaky pink; equal to "Old St. Anne's"; on the Sydney market to some extent. |
| | Streaky, very dark gray. |
| Rockley ... ... | Black and white, crinoidal; very good for both inside and outside work. |
| Rylstone ... ... ... | Pink and gray. |
| | Pink and white. |
| | Black and white. |
| Tamworth ... ... ... | Red, crinoidal; on the Sydney market to some extent. |
| Wellington, 5 miles east of | (Small pieces only.) |
| | White and pink; striped; equal to the French marble imported for columns; yields very different patterns according to the way it is cut. |
| Windellama ... ... | Black; used in the University floor. |

## Production of Marble.

| Year. | Quantity. | Value. |
|---|---|---|
| 1891 ... ... ... ... | 635 pkg. | £2,577 |
| 1892 ... ... ... ... | ........... ... | ............ .. |
| 1893 ... ... ... ... | .............. | .............. |
| 1894 ... ... ... .. | 8 pkg. | 80 |
| 1895 ... ... ... .. | .............. | ... .......... |
| 1896 ... ... ... ... | .. ........... | .............. |
| 1897 ... ... ... | .............. | .............. |
| *1898 ... ... ... .. | ............. | ..... ........ |
| Totals ... ... ... | 643 pkg. | £2,657 |

* Only quarry in active operation is that at Calula (?), owned by Mr. T. J. Robinson, of Orange. Machinery has been erected to dress and polish the stone.

# LIMESTONE.

Valuable beds of limestone belonging to several geological ages are widely distributed over New South Wales, by far the greater number of known deposits being situated in the eastern and central portions of the country; this is, in all probability however, merely a result of the fact that in these districts there is a much greater exposure of rock at the surface, whereas, in the western district the geological formations are obscured by Post-Tertiary deposits of soil, forming widespread plains.

The limestones are used for the preparation of quicklime, as flux for metallurgical processes, as building stones, and for the manufacture of hydraulic cement, as at Portland, near Cullen Bullen.

The following is a list of the localities where the principal deposits of limestone occur:—

| Locality. | Geological Age. | Locality. | Geological Age. |
|---|---|---|---|
| Barrington River ... | Carboniferous. | Marulan .. ... | Devonian. |
| Binalong ... ... | Silurian. | Molong ... ... | Silurian. |
| Bungonia ... ... | Devonian. | Mundarlo... ... | ,, |
| Bungwall ... ... | Carboniferous. | Queanbeyan ... | ,, |
| Capertee Valley ... | Devonian. | Rouchel Brook ... | Carboniferous. |
| Clarence Town ... | Carboniferous. | Tamworth ... | Devonian. |
| Cudal ... ... | Silurian. | Tarago ... ... | ,, |
| Cudgegong... ... | Devonian. | Terrawingee ... | Silurian (?) |
| Cullen Bullen ... | ,, | Wellington ... | ,, |
| Goodradigbee ... | Silurian. | Wombeyan ... | ,, |
| Jenolan ... ... | ,, | Yass ... ... | ,, |
| Macleay River ... | Permo-Carboniferous. | | |

In the accompanying table is given all the available information in regard to the composition of New South Wales limestones; it is to be regretted, however, that it is far from complete, as many of the best limestones have not been analysed.

## Analysis of New South Wales Limestones.

| Locality. | Moisture. | Combined Water. | $CaCO_3$. | $MgCO_3$. | $CO_2$. | CaO. | MgO. | SrO. | $Fe_2O_3$. | $Al_2O_3$. | Insoluble Silica. | Soluble Silica. | $SO_3$. | $P_2O_5$. | Organic Matter. | Alkalies |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Albury .. .. .. .. | ·05 | | .. | .. | 43·88 | 55·77 | trace | .. | ·26 | | trace | trace | trace | .. | .... | .... |
| Balranald . .. .. .. | 1·35 | 1·63 | .. | .. | 34·15 | 42·56 | 1·76 | .. | ·23 | 3·56 | 14·50 | .. | | ·11 | ·15 | .... |
| Bathurst .. .. .. .. | .. | .. | 95·97 | .. | .. | .. | | .. | .. | .. | | .. | .. | .. | .... | .... |
| Bobadah .. .. .. .. | | .. | 97·39 | .. | .. | .. | ·20 | .. | ·41 | | 1·76 | .. | | | .... | .... |
| Bulli .. .. .. .. | 3·95 | .. | 62·44 | ·36 | | .. | | .. | 4·09 | 2·96 | 23·09 | .. | .. | | .... | ·17 |
| „ .. .. .. .. | 2·82 | .. | 92·04 | 1·32 | | .. | | .. | ·63 | 1·02 | 1·94 | .. | .. | | .... | ·23 |
| Burragorang .. .. | .. | .. | 98·30 | | | .. | .. | | .. | .. | | .. | .. | | .... | ... |
| Bushy Hill, Scone .. .. .. | .. | .. | .. | | 40·27 | 48·70 | 1·84 | trace | ·70 | 1·05 | 6·45 | trace | trace | | ·74 | .... |
| Caloola .. .. .. | .. | . | .. | 42·64 | | .. | .. | .. | .. | .. | | .. | .. | | .... | .. . |
| Carwell, Rylstone .. .. .. | ·25 | | .. | .. | 25·60 | 32·59 | 3·18 | | ·19 | 2·86 | 33·84 | .. | trace | | 1·02 | .... |
| Clifton .. .. .. .. | .. | .. | 53·47 | .. | .. | .. | .. | .. | .. | .. | | .. | .. | . | .... | .... |
| Cootaminaby .. .. .. | .. | | | .. | .. | 46·59 | .. | | .. | .. | | .. | .. | | .... | .... |
| Cumberland, County of .. .. | 2·71 | .. | .. | .. | 24·78 | 30·02 | ·70 | trace | 4·47 | 2·17 | 34·93 | .. | .. | trace | .... | .... |
| Denman .. .. .. | ·56 | 1·35 | 38·41 | 29·43 | .. | .. | ·63 | | ·70 | | 22·71 | 5·45 | | trace | .... | ·93 |
| Gloucester .. .. .. | .. | .. | 89·00 | .. | | .. | .. | | .. | | .. | .. | | .. | .... | .... |
| Hay, Near .. .. .. .. | .. | .. | 59·50 | .. | .. | .. | ·90 | | 2·30 | 5·75 | 22·30 | .. | ·08 | .. | .... | .... |
| Ilford .. .. .. | .. | .. | 90·85 | .. | .. | ·80 | 1·98 | .. | 1·06 | | 5·14 | .. | | trace | .... | .... |
| Illawarra .. .. .. | 3·30 | .. | .. | .. | 28·89 | 36·73 | ·88 | trace | ·22 | 11·07 | 17·70 | trace | trace | ·19 | ·21 | (FeO ·76) |

## Analysis of New South Wales Limestones—*continued.*

| Locality. | Moisture. | Combined Water. | $CaCO_3$. | $MgCO_3$. | $CO_2$. | CaO. | MgO. | SrO. | $Fe_2O_3$. | $Al_2O_3$. | Insoluble Silica. | Soluble Silica. | $SO_3$. | $P_2O_5$. | Organic Matter. | Alkalies. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lue .. .. .. .. | | .. | 88·99 | 6·43 | .. | .. | 1·97 | .. | .. | ·80 | 2·00 | .. | .. | | .... | .... |
| Macleay River .. .. .. | .. | .. | 94·50 | | .. | .. | .. | .. | 1·90 | | 3·60 | .. | .. | | .... | .... |
| Marulan .. .. .. .. | ·65 | .. | 78·60 | .. | .. | | ·14 | .. | ·75 | [3·44 | 14·84 | .. | .. | ·10 | 1·18 | .... |
| Mount Kembla .. .. .. | 1·17 | .. | | .. | 19·36 | 24·64 | 1·62 | .. | 3·50 | 5·55 | 43·75 | .. | trace | | .... | .... |
| Mount Pleasant .. .. .. | ·85 | .. | | .. | 27·75 | 34·61 | 1·01 | .. | .. | 13·29 | 18·74 | .. | trace | ·15 | (FeO 1·36) | 2·48 |
| Narrabri .. .. .. .. | 1·15 | 2·49 | | .. | 5·19 | 7·50 | ·77 | .. | 3·80 | 1·00 | 77·90 | .. | .. | ·23 | .... | .... |
| Peak Hill .. .. .. .. | ·20 | .. | | .. | 36·89 | 44·52 | ·86 | 2·24 | ·22 | 1·12 | 12·80 | .. | trace | ·05 | (FeO ·14) | ·68 |
| Pinnacles .. .. .. .. | ·51 | ·77 | 67·74 | 24·91 | .. | .. | ·24 | .. | ·97 | ·99 | 3·47 | .. | trace | ·26 | .... | .... |
| Plumbago Creek, New England | 3·59 | .. | 69 20 | 1·94 | .. | | .. | .. | 3·19 | 1·94 | 20·40 | .. | | trace | .... | .... |
| Port Stephens .. .. | .. | .. | .. | .. | 36·41 | 46·47 | 2·08 | .. | ·16 | | 14·58 | .. | | .. | .... | .... |
| Prospect . .. .. .. | ·92 | .. | .. | .. | 24·72 | 27·83 | .. | .. | .. | 7·59 | 29·38 | .. | | .. | .... | .... |
| Tarrabandra .. .. .. | .. | .. | .. | .. | 42·90 | 54·60 | ·60 | .. | 1·75 | | ·16 | .. | · | .. | .... | .... |
| Tarrawingee .. .. .. | ·15 | .. | 85·90 | 1·18 | .. | | ·48 | .. | 1·02 | ·58 | 10·40 | .. | ·24 | .. | ·15 | .... |
| West Maitland .. .. .. | .. | .. | 87·32 | 1·71 | | .. | .. | .. | 2·04 | | 7·55 | .. | | .. | .... | .... |
| Wollongong.. .. .. | 2·77 | .. | 46·41 | 1·33 | · | | .. | .. | 2·92 | 10·02 | 36·55 | .. | .. | trace | .... | .... |
| Yessabar, near Kempsey .. | 1·64 | .. | 37·18 | 4·76 | .. | 3·87 | .. | .. | 11·33 | | 40·99 | .. | trace | trace | .... | .... |
| Wallerawang .. .. .. | | .. | | .. | 42·70 | 54·09 | ·56 | .. | 1·10 | | ·72 | .. | .. | .. | .... | .... |
| " .. .. .. .. | | .. | .. | .. | 42·33 | 53·42 | ·56 | .. | ·75 | trace | 2·90 | .. | · | ·11 | .... | .... |

### *Production of Limestone (Flux).*

| Year. | Quantity. | Value. |
|---|---|---|
| | Tons. | £ |
| 1889 ... ... ... | ............. | .. ......... |
| 1890* ... ... ... | 41,436·8 | 41,989 |
| 1891 ... ... ... | 74,057·0 | 65,357 |
| 1892† ... ... ... | 103,368·0 | 93,031 |
| 1893 ... ... | 130,635·0 | 111,041 |
| 1894 ... ... ... | 89,990·0 | 69,289 |
| 1895 ... ... ... | 104,194·0 | 68,160 |
| 1896 ... ... ... | 88,924·0 | 54,261 |
| 1897‡ ... ... ... | 67,590·0 | 41,798 |
| 1898§ ... ... ... | 9,253·0 | 5,783 |
| 1899 ... ... ... | 1,000·0 | 750 |
| Totals ... ... | 710,447·8 | 551,460 |

* 1,000 tons sent from Bungwall Quarries to Asphalt Works, Sydney.—Value not stated.
† Patent Asphaltum Co. forwarded 1,270 tons to their works in Sydney from quarries near Bungwall.
‡ Cockle Creek Works obtaining supply from Myall Lake District (Bungwall).
§ Mr. O'Neill still raising stone at Myall Lake. 200 tons sent away during the year. This came from quarries at Myall Lake.

### *Production of Lime.*

| Year. | Quantity. | Value. |
|---|---|---|
| | Tons. | £ |
| 1891 ... ... ... ... | 410 | 958 |
| 1892 ... ... ... ... | 403 | 822 |
| 1893 ... ... ... ... | ......... | ......... |
| 1894 ... ... ... ... | ......... | ......... |
| 1895 ... ... ... ... | ..... ... | ......... |
| 1896 ... ... ... ... | ......... | ......... |
| 1897* ... ... ... ... | 349 | 693 |
| 1898† ... ... ... ... | ......... | ......... |
| Totals ... ... ... | 1,162‡ | 2,473‡ |

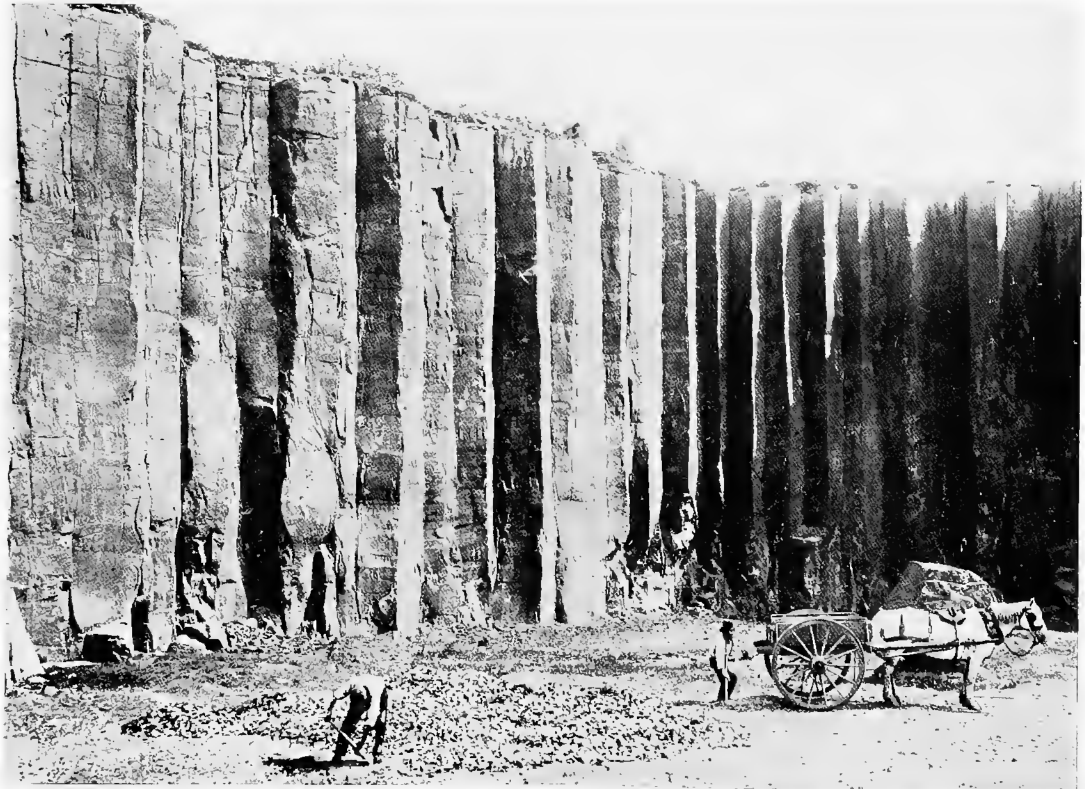
* The Cullen Bullen Works are now supplying large quantities of lime and cement to the building trade and others.—Annual Report, 1897.
† The extensive lime works at Cullen Bullen are still doing a large business in prepared lime and cement.—Annual Report, 1898.
‡ Note.—These figures represent exports only. See above notes *re* Cullen Bullen Lime Works.

# BUILDING STONE.

PROBABLY no city in the world has greater advantages than Sydney in regard to the possession of unlimited quantities of good building materials; for in the first place, the *Wianamatta shales* (and the clays derived from them), of which the highlands of the greater part of the County of Cumberland are composed, are suitable for the manufacture of excellent bricks, and, secondly, the *Hawkesbury sandstone*, which underlies the whole of the Sydney District, and which outcrops all round the harbour, forms a building stone which is at once durable, easily worked, and of a most attractive appearance. It varies in colour from white to buff, or light brown, and has been largely used in the construction of the University, Government and municipal offices, cathedrals and churches, banks, insurance societies, and other mercantile houses. There are sandstone quarries at Mosman, Pyrmont, Hunter's Hill, Parramatta, Randwick, and Waverley. The *Desert Sandstone* (of Upper Cretaceous age), which occurs in considerable quantities in the north-western portions of New South Wales, forms a good building stone, and resembles the Hawkesbury sandstone in a marked degree. It has been used to some extent in the town of Wilcannia, on the Darling River.

Somewhat similar freestones are obtained in the *Permo-Carboniferous Coal Measures*, as at Morpeth, Muswellbrook, Lambton, East Maitland, and Waratah. The Waratah stone is fine in texture, and of a gray colour, and is suitable for monumental work ; it also yields good grindstones.

Another class of stone which is rapidly coming into favour with Sydney architects and engineers is the Bowral *syenite*, or "*trachyte*" as it is erroneously termed in the building trade. It occurs as an intrusive boss forming what is known as the Gib Mountain, between Bowral and Mittagong, about eighty miles from Sydney, on the Great Southern Railway. This syenite is a fine-grained, hard, crystalline rock, and therefore somewhat difficult to dress, but it is extremely durable, and it takes an exceedingly fine polish. It occurs in two colours, viz., light gray and dark gray. The light gray stone looks extremely well when roughly dressed, and a very fine architectural effect can be produced by relieving it with a certain proportion of the darker stone in a polished condition. The Bowral syenite has been used in the construction of the piers of the Hawkesbury Bridge; the Equitable Life Assurance Society's offices in George-street are entirely built of it, as is also the lowest story of the offices of the Mutual Life Insurance Company of New York in Martin-place.



*Photographed by E. F. Pittman.*

STONE QUARRIES AT KIAMA.

Sheet of Augite-andesite, showing Columnar Structure.

The following is the composition of the Bowral syenite according to an analysis made by Mr. J. C. H. Mingage:—

| | |
|---|---|
| Moisture at 100° ... ... ... ... ... | ·68 |
| Combined water .. ... ... ... ... | 1·52 |
| Silica ... ... ... ... ... ... ... | 57·14 |
| Alumina ... ... ... ... ... ... | 16·13 |
| Ferric oxide ... .. ... ... ... ... | 4·69 |
| Ferrous oxide ... ... ... ... ... | 4·00 |
| Manganous oxide ... ... ... ... ... | trace. |
| Lime ... ... ... ... ... ... ... | 3·44 |
| Magnesia ... ... ... ... ... ... | ·63 |
| Potash ... ... ... ... ... ... | 5·07 |
| Soda ... ... ... ... ... ... ... | 4·87 |
| Phosphoric acid ... ... ... ... ... | ·25 |
| Carbonic acid ... ... ... ... ... | 1·42 |
| Sulphuric acid ... ... ... ... ... | ·30 |
| Chloride of sodium ... ... ... ... ... | ·04 |
| | 100·18 |

*Granite*, suitable for engineering or architectural purposes, occurs in great quantities in many parts of New South Wales. The deposits near Moruya, consisting of dark gray granite, are about the most convenient to Sydney, as the stone can be conveyed to the city by water carriage. The same may be said of the Trial Bay—a pale pink variety of granite; it is worthy of note that the mica in this granite does not crumble away in polishing, as is the case with the Moruya and other New South Wales granites. Fine red granite occurs at Gabo Island, near Cape Howe.

*Basalt*, suitable for macadamising, occurs at Kiama, and at the Pennant Hill quarries, about three miles to the north-east of Parramatta. Numerous dykes of dolerite and basalt also intersect the Hawkesbury rocks, in the neighbourhood of Sydney, and in several localities these intrusive dykes have not only baked the sandstones near the plane of contact, but have also induced a marked columnar structure in them. The rock thus metamorphosed has been extensively used for road-making and also for concrete. In the Prospect basalt quarry the rock is capable of being hewn in large blocks which could be sawn into slabs for paving stones.

Along the south-coast between Wollongong and Gerringong the Coal Measures include interbedded sheets of *augite-andesite;* these are of great thickness, and at Kiama they are extensively quarried, the stone being broken and used for road-making and for railway ballast. The andesite has a columnar structure which greatly facilitates quarrying operations. At Port Kembla this columnar rock is being quarried in large blocks for use in the construction of the mole or breakwater for the deepwater harbour at that place.

A very fine ornamental rock which is destined to be greatly used in the future for internal decorations occurs over a large area in the Cowra district. It is a dense *porphyry*, having a dark green base with white or cream-coloured crystals of felspar scattered through it. It is a hard rock, but one which, for ornamental purposes, will well repay the labour necessary to dress and polish it.

*Serpentines* occur in many districts in New South Wales; they are of various shades of green; but, as a rule, there is an absence of red colour in them. The Bingara serpentine is suitable for monument bases and outdoor work generally, and the Cowra serpentine is also of good quality. Precious serpentine occurs at Byng, and is suitable for small beadings for decorative architecture.

*Slates* for roofing purposes have been quarried at a number of places, such as Moruya, Gundagai, Millamurrah, Caloola, and Newbridge; the industry, however, was unsuccessful, owing principally to the fact that the slates were too hard and not sufficiently fissile to be profitably worked. It is probable, however, that more satisfactory material will yet be discovered, and there is no doubt that large quantities of slate occur, suitable for door steps, the walls of urinals, &c.

*Marble* has already been referred to under a separate heading.

*Sharpening Stones.*—About eight miles to the north-east of Mudgee, near the Cassilis road, there are extensive deposits of altered siliceous slates, which have been quarried, to a considerable extent, for use as sharpening stones or oil stones. This Mudgee stone, as it is termed, has a good "bite" on steel, and is well known in the trade, being regularly supplied to the Sydney market. The slates are of Upper Silurian age, and appear to have been hardened or metamorphosed owing to the intrusion of a granite massif.

Samples of all the stones referred to above can be seen in the Geological Museum.

*Production of Stone.*

| Building. | | | Ballast. | |
|---|---|---|---|---|
| Year. | Quantity. | Value. | Quantity. | Value. |
| | No. | £ | Tons. | £ |
| 1891 | 4,735 | 5,205 | 619 | 713 |
| 1892 | 2,478 | 2,838 | 224 | 276 |
| 1893 | 850 | 855 | 132 | 166 |
| 1894 | ......... | ......... | ......... | ......... |
| 1895 | ......... | ......... | ......... | ......... |
| 1896 | ......... | ......... | ......... | ......... |
| 1897 | ......... | ......... | ......... | ......... |
| 1898 | 1,459 | 842 | ......... | ......... |
| 1899 | ......... | ......... | ......... | ......... |
| Totals | 9,522 | 9,740 | 975 | 1,155 |

*Slates.*

| Year. | Quantity. | Value. |
|---|---|---|
| | No. | £ |
| 1881 ... ... ... | 18,000 | 202 |
| 1882 ... ... ... | ........ ... * | ............ |
| 1883 ... ... ... | 30,000† | 337 |
| 1884‡ .. ... .. | ............ | ............ |
| 1885§ ... ... ... | ............ | ............ |
| 1886 ... ... ... | ............ | ............ |
| 1887 ... ... ... | ............ | ............ |
| 1888 ... ... ... | ............ | ............ |
| 1889 ... ... ... | ............ | ............ |
| 1890 ... ... ... | ............ | ............ |
| 1891 ... ... ... | 31,234 | 351 |
| 1892–8 ... ... ... | ............ | ............ |
| 1899 ... ... ... | ............ | ............ |
| Totals ... ... | 79,234 | 890 |

* Quarries at Gundagai, opened up with great energy. † *Also* 10,000 feet of slabs.
‡ Aust. Slate Co. (Gundagai) completed erection of their machinery.
§ Aust. Slate Co. still working.
N.B.—The colonial slates have now been out of the market for years.

# MINERAL WATERS.

MINERAL springs are fairly numerous in New South Wales, and their waters vary considerably in composition; thus while some are said to possess valuable medicinal properties, others have been successfully introduced as table waters. Chalybeate springs are common in the Permo-Carboniferous Coal Measures and the overlying Hawkesbury Sandstones; but in only one instance, viz., at Mittagong, has any attempt been made to utilise them.

*The Mittagong Spring* is the source of a considerable deposit of iron ore (brown hematite), and it was for the purpose of smelting this ore that the Fitzroy Ironworks were started many years ago. A shed has been erected over this spring, and facilities have been provided for enabling visitors and local residents to drink the waters.

The Mittagong chalybeate water has been analysed by Mr. J. C. H. Mingaye, in the Laboratory of the Department of Mines, and its composition is as follows:—

| | Grains per gallon. | In 1,000 parts. |
|---|---|---|
| Bicarbonate of iron ... ... | 5·985 ... | ... ·0855 |
| ,, magnesium ... | 2·243 ... | ... ·0320 |
| ,, calcium ... | 2·041 ... | ... ·0291 |
| Chloride of sodium ... ... | 2·158 ... | ... ·0308 |
| ,, potassium ... | 2·042 ... | ... ·0291 |
| ,, magnesium ... | 1·296 ... | ... ·0185 |
| Total solids = | 15·765 | ·2250 |

Free ammonia, nil. Organic or albuminoid ammonia, nil. Nitrogen as nitrates, nil. Nitrogen as nitrites, nil. "Colour in a two-feet tube, light brown. Reaction, acid, due to carbonic acid gas. Taste, inky. Odour, earthy."

Amongst the other mineral springs which have hitherto been discovered, four are deserving of special mention. These are (1) the Ballimore spring; (2) the Rock Flat spring, near Cooma; (3) the Jarvisville Spring, near Picton; and (4) the Bungonia Spring.

*The Ballimore Spring* is situated at Ballimore, on the Talbragar River, about twenty miles north-east of Dubbo. In this case the water did not form a natural spring at the surface, but was discovered in a diamond drill bore which was put down, in the year 1886, to search for coal.

*Photographed by E. F. Pittman.*

MINERAL SPRING AT ROCK FLAT, NEAR COOMA.

According to a report by Mr. W. H. J. Slee, Superintendent of Diamond Drills, at a depth of 540 feet the drill at Ballimore passed through a seam of coal five feet two inches in thickness, and while boring for a second seam of coal, ten feet below the first, mineral water commenced to flow to the surface at the rate of 1,000 gallons per hour, and it was found that the pressure was sufficient to cause it to continue flowing through perpendicular piping thirty feet above the surface. The water contains a considerable quantity of free carbonic acid gas.

A complete analysis of this water was made by Mr. J. C. H. Mingaye, Analyst to the Department of Mines, showing it to have the following composition:—

| | Grains per gallon | In 1,000 parts. |
|---|---|---|
| Bicarbonate of Sodium ... ... | 183·10 ... ... | 2·6157 |
| ,, Potassium ... | 12·83 ... ... | ·1833 |
| ,, Lithium ... ... | ·05 ... ... | ·0007 |
| ,, Calcium .. ... | 11·38 ... ... | ·1625 |
| ,, Magnesium ... | 9·36 ... ... | ·1337 |
| ,, Strontium ... | trace. ... ... | trace. |
| ,, Iron ... ... | ·70 ... ... | ·0100 |
| Chloride of Sodium ... ... | 6·92 ... ... | ·0988 |
| Alumina ... ... ... ... | trace. ... ... | trace. |
| Silica ... ... ... ... | ·28 ... ... | ·0040 |
| Total fixed matter = | 224·62 | 3·2087 |

Free Ammonia... ... ... ... 0·052 parts per 100,000
Organic, or Albumenoid Ammonia... ·003 ,, ,, ,,
Specific gravity of water at 65° F. = 1·00359.
Trace of Phosphoric Acid present.
The water has a pleasant taste, and is highly charged with Carbonic Acid.

The Ballimore water has been placed upon the market as an aerated table-water under the name of *Zetz Spa*, and is understood to have a considerable sale.

*The Rock Flat Spring.*—This is a natural spring which comes to the surface on the bank of Rock Flat Creek, in the Parish of Dangelong, County of Beresford, about ten miles to the south-east of the town of Cooma. The water issues from near the base of a small rocky mount composed of highly inclined beds of quartzite of Devonian (?) age, and the surface of the flat in the vicinity of the spring is composed of tufaceous limestone which has been deposited there by the water. The water is discharged at the rate of about fifty-four gallons per hour; it has a pleasant taste, and is strongly charged with carbonic acid gas. This spring has been known for many years, being close to the main road from Cooma to Nimitybelle, and it was a favourite camping-place for teamsters on account of the agreeable taste of the water; it was only recently, however, that arrangements were made to bottle the water, and place it upon the market under the name of *Koomah Spa.*

The following analysis of the Rock Flat mineral water was made by Mr. J. C. H. Mingaye, Analyst to the Department of Mines :—

| | Grains per gallon. | In 1,000 parts. |
|---|---|---|
| Bicarbonate of Sodium ... | 45·29 | 0·647 |
| ,, Potassium ... | 17·15 | ·245 |
| ,, Lithium ... | nil. | nil. |
| ,, Calcium ... | 52·08 | ·774 |
| ,, Magnesium ... | 22·40 | ·320 |
| ,, Strontium ... | strong trace | strong trace |
| ,, Iron ... | nil. | nil. |
| Chloride of Sodium ... | 5·04 | ·072 |
| Nitrate of Soda ... | trace | trace |
| Alumina ... | trace | trace |
| Silica ... | ·56 | ·008 |
| Total fixed matter = | 142·52 | 2·066 |

"Remarks :—Water highly charged with carbonic acid gas. An excellent sample of table water."

*The Jarvisville Mineral Spring.*—This is a natural spring which issues from the face of a cliff of Hawkesbury Sandstone on the Jarvisville Estate, about a mile from the Picton Railway Station. The following analysis of this water was made by Mr. J. C. H. Mingaye, F.C.S., in the Laboratory of the Department of Mines :—

| | Grains per gallon. | In 1,000 parts. |
|---|---|---|
| Chloride of Sodium ... | 100·620 | 1·4374 |
| ,, Magnesium ... | 26·211 | ·3744 |
| Bicarbonate of Calcium ... | 19·340 | ·2762 |
| ,, Magnesium ... | 50·390 | ·7208 |
| Sulphate of Potash ... | 12·172 | ·1738 |
| ,, Lime ... | 1·985 | ·0284 |
| Silica and Silicates ... | ·812 | ·0116 |
| Alumina ... | trace | trace |
| Oxide of Iron ... | trace | trace |
| Organic matter ... | trace | trace |
| | 211·530 | 3·0226 |

"Reaction, alkaline. Taste, saline. Odour, when heated, organic. Colour, in a two-feet tube, pale green. Poisonous metals, nil."

*The Bungonia Spring.*—This is a natural spring of mineral water situated in Bungonia Creek, about a mile and a half to the west of the township of Bungonia. The water has an agreeable taste, and is charged with carbonic acid gas, which can be seen bubbling up through an earthenware pipe which has been placed in a vertical position over the orifice through which the water flows. The water probably obtains its mineral constituents by percolating through beds of Devonian limestone which occur in the vicinity. A considerable quantity of tufaceous limestone can be seen for some distance up Bungonia Creek, having evidently been deposited by the water. A sample of the water taken recently has been analysed by Mr. H. P. White, Assistant Analyst, and found to have the following composition :—

| | Grains per gallon. | In 1,000 parts. |
|---|---|---|
| Bicarbonate of Calcium | 142·6896 | 2·0384 |
| ,, Magnesium | 31·8679 | ·4552 |
| ,, Iron | 1·0902 | ·0155 |
| ,, Lithium | ·3281 | ·0046 |
| ,, Strontium | trace | trace |
| ,, Sodium | 12·5778 | ·1796 |
| Sulphate of Sodium | 1·2567 | ·0179 |
| ,, Potassium | 1·6920 | ·0241 |
| Chloride of Sodium | 12·8617 | ·1837 |
| Silica and Silicates | 2·2960 | ·0328 |
| Total fixed matter = | 206·6600 | 2·9518 |

Free Ammonia = 0·0026 per 100,000 parts.

"The water contained suspended matter equal to 5·807 grains per gallon, and which consisted of clay, with some ferric oxide, and organic matter. The analysis was made of the filtered water."

# ARTESIAN WATER.

ALTHOUGH Artesian water contains an appreciable amount of mineral salts in solution, it cannot in a strict sense be termed one of the mineral resources of the Colony ; nevertheless no apology is perhaps necessary for referring to it in this volume, as its occurrence is directly connected with the geology of the country, and there can be no question that it is a subject of the utmost importance to our industrial progress. Constantly recurring droughts, often of several years duration, have proved so disastrous to the pioneers of the pastoral industry in the arid plains of the western division of the Colony, that much of the land came to be regarded as worthless desert. Indeed nothing more thoroughly desolate can be imagined than the appearance of the western plains in a season of drought. For scores of miles there is an utter absence of vegetation, unless the sombre, stunted scrub, which occurs in belts at intervals, can be dignified by such a name; the only noticeable variation is from "black soil" to "red sand," or, worse than either, to "sandhill and claypan" country. The scorching heat and ever recurring sensation of thirst are accentuated by the mocking *mirage*, whose phantom lakes elude all attempts to approach them. The traveller in this desert experiences a peculiar feeling of isolation and depression only to be compared to that of being alone at sea. What then must be the state of mind of the pastoralist as he rides his rounds on the estate? He has sunk all his capital in the vain endeavour to improve this inhospitable country, yet the only relief to the dead-level of the landscape is provided by the carcases of his perished stock which dot the plain, and but serve to remind him of his constantly increasing losses. However, thanks to the efforts which resulted in the discovery of the priceless store of underground water, the outlook is now much more promising in many districts where the rainfall is both scanty and uncertain.

The term "Artesian" is used in reference to water which has collected underground under such a pressure as will enable it, when the pressure is relieved by a bore, to rise *above the surface* of the ground. The term "Sub-Artesian" is applied to water occurring under sufficient pressure to cause it to rise a certain height in a bore or well, but not as high as the surface. The word "Artesian" is derived from Artois, the name of one of the ancient provinces of France, where the first overflowing well was excavated by boring.

*History of the discovery of Artesian Water in New South Wales.*—An attempt to bore for Artesian water was made as far back as Novr., 1851. In the year 1850, a board was appointed to consider the best means of boring for Artesian water with the object of providing a water supply

*Photographed by E. F. Pittman.*

THE DROUGHT-STRICKEN WEST.

View of the unimproved country in the vicinity of Pera Bore. The appearance of water in the background is an illusion, and is due to *mirage*.

for the city of Sydney. The late Rev. W. B. Clarke was the chairman of the board, but he does not appear to have been at all sanguine as to the success of the experiment. The boring was started within the walls of Darlinghurst Gaol, but operations were very much delayed by the discovery of the gold-fields, and by the difficulty of obtaining workmen familiar with Artesian boring. When the bore had reached a depth of seventy-five feet, the tools were reported to be fast in the hole, and every method of extricating them was tried without success. A shaft was then sunk to relieve the tools, when it was found that they had been wedged in by a large steel punch, which had been accidentally or maliciously thrown down the bore. Owing to the difficulties encountered in the work and the uncertainty as to ultimate success, the enterprise was abandoned without any greater depth having been obtained. (*Legislative Council Papers.*)

Several bores recently put down through the Hawkesbury sandstones in the vicinity of Sydney have proved that Artesian water does not occur in the district.

In August, 1879, Mr. H. C. Russell, the Government Astronomer, read an interesting paper, entitled "The River Darling—the water which should pass through it," before the Royal Society of New South Wales. The author mentioned that the basin or drainge area of the Darling is considerably more than 200,000 square miles in extent, and that of this area fully 100,000 square miles are occupied by the western slopes of the Dividing Range, stretching from Orange northwards into Queensland. He stated that in an *average year* these slopes of the Dividing Range received a rainfall of about thirty inches, while in the more western plains drained by the Darling, the average rainfall is from ten to twenty inches. Assuming, however, that only *two* inches of that rainfall reached the channel of the river, Mr. Russell showed that the Darling would require to flow, without cessation throughout the year, as a river 200 feet wide, 100 feet deep, and with a velocity of one mile per hour, in order to carry off the supply of water. He pointed out that, as a matter of fact, the Darling, in a year of average rainfall, is not navigable for more than six months, and, even then, does not carry off more than one-third of the water just indicated; that in summer it is very low, and perhaps ceases running; that the actual width at Bourke is 180 feet; and that the velocity of the river in flood time has been carefully measured and found to be only two-thirds of a mile per hour. He raised the question "What then becomes of the rain-water?" and the conclusion he arrived at was that it must, as is known to be the case with the waters of the Barcoo and some other rivers, "sink into the ground to flow at some lower level." He further stated that "these considerations point to an inexhaustible supply of water from wells, and we cannot be surprised that so many wells have been made, and found to confirm the ideas here presented, and there can be no doubt that beneath the surface of our flat country there is an unlimited supply of good water."

In a subsequent paper Mr. Russell showed, as the result of observations extending over ten years, that the average annual discharge of the river Darling, at Bourke, only amounted to 1·46 per cent. of the total rainfall within its drainage area, while observations made with regard to the Murray River, whose catchment is not unlike that of the Darling in outward appearance and rainfall, proved that its discharge amounted to 25 per cent. of the rainfall.

At the time the first paper just referred to was written there were no artesian wells in New South Wales or Queensland, and Mr. Russell was unaware of the geological evidence of the existence of an Artesian basin in either of these colonies. But although, in the absence of this knowledge, he could not have anticipated the occurrence, under the western plains, of *water under pressure* (that is to say, water that would rise above the surface of the ground, or Artesian water), there is no doubt that the remarkable statements advanced by him, as to the disappearance underground of so large a proportion of the rainfall in the Darling River catchment area, attracted the attention of pastoralists and others, and led to the operations which resulted in the ultimate discovery of the Artesian supply.

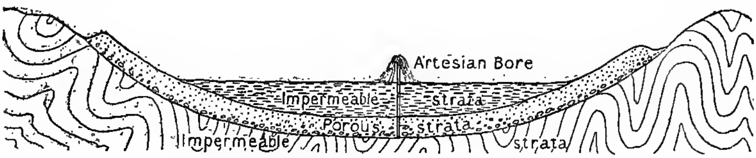
In the following year, 1880, the first actual discovery of Artesian water was made at two places known as Wee Wattah and Mullyeo, in the Killara Pastoral Holding, between the Darling and Paroo Rivers. Mr. David Brown, Manager for Messrs. Officer Brothers, put down some bores for water at these places, being guided, in his selection of sites for the bores, by the occurrence on the surface of the plains of some natural springs known as "Mud Springs." These mud springs are now known to be indications of the occurrence of artesian water at shallow depths, and they consist of more or less circular mounds of clay and gravel, in the centres of which are springs. At the Wee Wattah spring a bore, four inches in diameter, was put down from the bottom of a well 110 feet deep, and, after an additional depth of thirty-four feet had been bored, a supply of Artesian water rose in the pipes to a height of twenty-six feet above the surface of the ground. The temperature of the water was 82° Fahr., and at first the flow was at the rate of fifteen gallons per minute, but subsequently the pipes became more or less choked by sand, and the supply of water fell off somewhat. The strata passed through were described as consisting of clay and drift. Five bores, the deepest being 142 feet, were put down at Wee Wattah, and water was obtained in all of them.

At Mullyeo, close to some more mud springs, and at a distance of ourteen miles from Wee Wattah, Mr. Brown obtained Artesian water at depths of from seventeen to forty-nine feet from the surface; the temperature of the water was 63° Fah., and the flow was at the rate of twelve gallons per minute. Four bores were put down at this site, and a flow of water was obtained in each of them.*

* "Notes on the occurrence of Artesian wells in the Albert district," by C. S. Wilkinson. *Procs. Linn. Soc. N. S. Wales*, 1881, VI., p. 155.

Mr. W. W. Davis, the owner of Kerribree Station, was, however, the first to demonstrate the success of Artesian boring on an extensive scale. The first bore put down by him was 1,073 feet in depth, and yielded 350,000 gallons of water per day; the second was still more successful, for, at a depth of 1,340 feet a flow of 1,750,000 gallons per day was obtained. Many other pastoralists followed Mr. Davis's example, and fine Artesian wells were constructed in various drought-stricken parts of the country. In 1884 the Government undertook the work of providing water along roads and stock routes in the north-western district by inviting tenders for sinking Artesian wells at specified localities. Many fine flows have been obtained in this manner, and roads which were formerly impassable, owing to the want of water (such as the road from Wanaaring to Milparinka) are now open to traffic. A complete list of the Government and private bores, with their flows and temperatures, is appended. Up to the present time sixty-four Government bores have bave completed, and ther total yield is estimated at 31,762,415 gallons of water per day, while ninety-four private bores have been estimated to yield a total of 45,499,900 gallons per day. In all, therefore, there are 158 bores, which are estimated to yield 77,262,315 gallons of water per day. It should be mentioned, however, that the details of the private bores are supplied by the owners, and it is probable that the estimated yields are, in some cases, too high. The details of the Government bores are quoted from a return prepared by Mr. J. W. Boultbee, the Superintendent of Public Watering Places. It will be noticed that the Dolgelly bore is the deepest in the Colony, its depth being 4,086 feet, its flow 745,200 gallons per day, and the temperature of its water 130° F. The greatest temperature yet recorded for the water from any bore in New South Wales is 148° F., in the case of the Goondabluie private bore, the depth of which is 2,800 feet. In Queensland, however, considerably higher temperatures have been recorded from some of the bores, the highest being 196° F., at the Dagworth bore, in the Winton District. This bore has a depth of 3,335 feet, and a flow which has been estimated at 775,000 gallons per day.

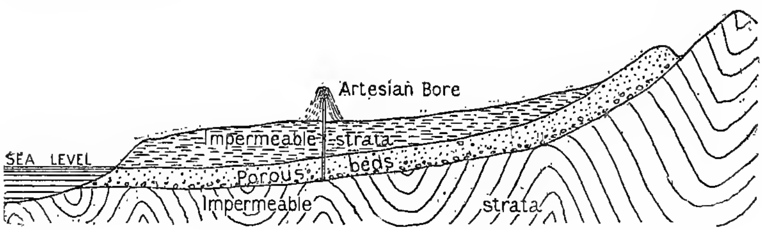
*Conditions governing the occurrence of Artesian Water.*—In geological text books the conditious necessary for the occurrence of Artesian water are generally described as follows:—There must be a porous bed or series of porous strata (sands and gravels), occupying a basin-shaped depression, and dipping on all sides from the margin of the basin towards its centre. The porous beds must outcrop at the margin of the basin at a higher altitude than that of the surface of the ground where it is proposed to bore for Artesian water. The porous beds must be underlaid by granite, palæozoic slate, or some other impervious rock which will form a watertight floor for the basin, and they must also be overlaid by impervious strata of such material as clay or shale, to serve as a watertight covering, and prevent the leakage of the water in an upward direction; in short, the porous stratum must be sandwiched in between an impervious floor and an equally impervious roof. The porous rocks, where they outcrop at a high level on the margin of the basin, act as the intake beds; a considerable proportion of the rain which falls on the surface at these high altitudes is absorbed by the intake beds, and gradually sinks down in them in the direction of their dip, accumulating in the centre of the basin, and in course of time the porous rocks are in the condition of a sponge saturated with water. But the water thus




SECTION OF AN IDEAL ARTESIAN BASIN.

confined must necessarily occur under considerable hydrostatic pressure, the amount of pressure or "head" at any point depending upon the altitude of the intake bed above that point. When a bore is put down and intersects the water-bearing stratum at a low level, the pressure at that point is relieved, and the water will rise through the bore and above the surface to a height somewhat less than that of the outcrop of the intake bed, the deficiency in the height being chiefly due to the resistance offered by the sand or gravel to the percolation of the water.

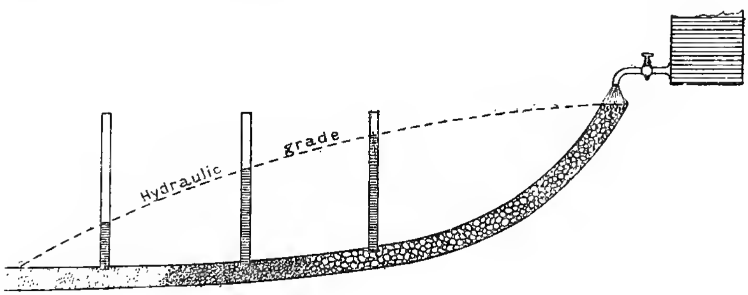
The foregoing may be regarded as the description of an ideal Artesian basin; but, as a matter of fact, most of the Artesian basins of the world are really one-sided basins—that is to say, that the porous strata outcrop at only a portion of their circumference, and that their dip is more or less regular and continuous to the other side, instead of towards a central point.




SECTION OF A ONE-SIDED ARTESIAN BASIN.
With leakage to the sea.

The term Artesian basin is, therefore, somewhat misleading, the structure being more properly that of a *half basin;* however, the use of the word has become general, and it may perhaps be retained in the absence of a better term. The great Artesian basin of Queensland, New South Wales, and South Australia is one of the latter type, the intake beds outcropping at high levels along its eastern and north-eastern sides only, while the remainder of the water-bearing formation is hidden under the superficial deposits of Pleistocene and Recent clays and sands forming the extensive plains of the interior of the colonies. Moreover, there are strong reasons for believing that there is an extensive leakage of the water from this basin into the sea in the neighbourhood of the Gulf of Carpentaria, in which case the pressure would be hydraulic instead of hydrostatic. Any accumulation of water, whether underground or on the surface, must eventually become salt unless it have an outlet, since the water will continue to dissolve saline matter from the rocks or soil; it is reasonable to conclude, therefore, that all Artesian basins from which potable water is obtained must have leakage, either direct to the ocean, or through valleys of denudation which have cut through the overlying strata and exposed the porous beds. It follows, therefore, that these basins would be hydraulic and not hydrostatic.

The question has been asked, "What causes the water to rise above the surface of the western plains in bores, if it be a fact that there is an extensive leakage from the basin into the ocean?" Professor David has shown, by an ingenious experiment, that the resistance offered by the sands and gravels, through which the water has to percolate before it reaches the sea, is sufficient to maintain the pressure necessary to force the water to the surface when bores are put down. In the experiment a bent lead pipe, with the convexity downwards, was employed to represent a section of a one-sided Artesian basin. The pipe was filled with sand, coarse shot, and marbles in consecutive order, to represent beds of decreasing porosity. Three vertical glass tubes were luted




into holes in the lead pipe, tapping respectively the parts of the pipe filled with sand, shot, and marbles. The lower end of the pipe was loosely stopped with a brick, to keep the materials in their places. Water was then poured into the upper end of the pipe until the latter was filled, and as the water escaped through the lower end more was poured in, so as to keep the pipe full. The water ascended the three vertical glass tubes, and remained stationary at a certain height in each. A line drawn from the point of intake through these three points in the glass tubes to the point of outlet represents the hydraulic grade, and Professor David showed that in this case it had the form of a convex curve, the convexity being uppermost. He argued that if the Artesian basin of Australia be hydraulic (which it would be if there be leakage to the sea), the hydraulic grade would have the form indicated by the experiment, and, consequently, very little fall might be expected in the hydraulic grade near the central portions of the basin.*

The resistance offered to the flow of water in porous beds is also sufficient to cause it to rise above the surface in bores put down in Artesian basins in which the porous beds have no impervious covering of clay or shale. The Perth (West Australian) Artesian basin is a case in point. It is a one-sided basin with leakage into the ocean on its western side. The porous beds consist of a calcareous sand-rock of Æolian origin, and these occur from the floor of the basin right up to the surface, there being no continuous impermeable strata overlying them; nevertheless, the water rises well above the surface in bores. It is evident in this case that the water has to meet not only the resistance offered by the sand-grains in its passage to the sea, but also the resistance to its upward ascent by the beds of sand-rock above it. In short, if sand-rock, porous though it be, offer such resistance to the lateral flow of water, it must offer even greater resistance to its vertical ascent, and hence it can be easily understood that when the pressure is suddenly relieved by a bore the water will flow above the surface.

It appears, therefore, that an impermeable covering is not a necessary condition for an Artesian basin, provided the porous intake beds outcrop at a sufficient altitude above the site of the borehole to supply the necessary "head."

*Geological Structure of the Artesian Basin of New South Wales.*— What is generally termed the New South Wales Artesian Basin has an area of about 83,000 square miles, and is in reality the south-eastern portion of the Great Australian Artesian Basin. Its boundary within this Colony is shown approximately on the mineral map at the end of this volume, and it extends to the west into the Colony of South Australia, and northwards right through Queensland, a distance of about 900 miles, to the Gulf of Carpentaria. During the Triassic period, this area formed a vast fresh-water lake or estuary, while owing to subsequent subsidence, which let in salt-water from the ocean, a considerable portion of it was, during Cretaceous times, occupied by an inland sea, such, for example, as would be formed by an extension southwards of the present Gulf of Carpentaria.

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* Journ. R. Soc. N.S. Wales for 1893, XXVII, p. 428.


MAP OF
AUSTRALIA
SHOWING THE EXTENT
(AS FAR AS KNOWN)
OF THE
GREAT ARTESIAN BASIN
REFERENCE
ARTESIAN BASIN
English Miles
0 100 200 300 400 500 600
140 Longitude 145 East of 150 Greenwich 155
INDIAN
OCEAN
SOUTHERN
OCEAN
SOUTH PACIFIC OCEAN
WESTERN
AUSTRALIA
SOUTH
AUSTRALIA
Northern
Territory
QUEENSLAND
NEW SOUTH
WALES
VICTORIA
TASMANIA
NEW GUINEA
Dutch Territory
German Territory
British
Bismarck Archipelago
Celebes
Banda Sea
Flores Sea
Arafura Sea
Gulf of Carpentaria
Great Australian Bight
Arnhem Land
Kimberley District
Sydney
Brisbane
Adelaide
Melbourne
Perth
Hobart

62326

In dealing with the geology of the New South Wales portion of the basin, it will be necessary to refer to :

(1) The rocks forming its outer margin and its floor,
(2) The porous intake beds, and
(3) The overlying formations.

(1.) The rocks of which *the outer margin and floor* of the basin are composed consist chiefly of sediments of Silurian, Devonian, and Carboniferous age, as well as granite and other igneous rocks. The northern portion of the Dividing Range is formed of granite and indurated claystones of Carboniferous age, and these bound the Artesian basin on its eastern side for a considerable distance from Texas, on the Queensland border, towards the town of Dubbo. Near Dubbo Silurian slates are seen, but the junction of these with the Carboniferous claystones to the north-east is obscured by basalt flows. From Dubbo the edge of the basin follows a course which may be approximately described as down the Bogan River to its junction with the Darling; thence along the latter river to Bourke, and thence in a general westerly direction to the South Australian border. This boundary can only be accurately defined by boring, but the bores already put down have shown that it approximates to the course just described.

The rocks bounding this southern margin probably consist for the most part of Silurian slates and Devonian quartzites; owing to the recent superficial deposits covering the plains it is only rarely than an outcrop of the underlying rocks can be seen, but Silurian slates occur near Dandaloo and at several localities along the course of the Bogan; they can be seen outcropping in the banks of the Darling at Brewarrina; they form the base of Mount Oxley near Bourke; and they are again met with in the Barrier Ranges. Devonian quartzites occur near Wilcannia, and between that town and the Barrier Ranges.

It is just possible that there may be a gap in this southern barrier in the neighbourhood of Wilcannia, and that through this gap there may be a narrow extension of the Artesian water-bearing beds southwards along the course of the Darling River, and under the Tertiary (Eocene) deposits, which are at least 900 feet thick near Wentworth. The truth or incorrectness of this hypothesis can only be proved by boring, as the geology of most of the country is hidden by deposits of flood soil, but the bores which have already been put down to test the question seem to show that, if there be a southern extension of the basin, it must be a very narrow one.

The rocks just described as bounding the eastern and southern edges of the basin, also form, by their extension westwards and northwards, its floor or bed. Being all crystalline or highly metamorphosed, they are impermeable, and they thus act as bed-rock in preventing the downward percolation of the water stored in the porous beds of the basin. This floor of the old Triassic Sea was a very irregular one, as is proved by the variable depths of the Artesian wells. There was also a number of islands in the sea, the evidence of which is seen in the patches of older rocks which, in places, form the present land surface within the boundaries of the Artesian basin ; among these may be mentioned the Silurian areas of Mount Browne and the Koko Ranges ; the granite patches of Tibbooburra and Keribree ; the felspar-porphyry forming Mount Foster, etc., etc.

(2.) *The Porous Intake Beds.*—For some years after the first Artesian wells were constructed it was believed that porous rocks of Lower Cretaceous age (the Rolling Downs Formation of Queensland), were the sources of the water ; indeed the officers of the Geological Survey of Queensland appear to be still of that opinion. In 1895 Mr. R. L. Jack, Government Geologist of the northern colony, read an interesting paper at the Brisbane Session of the Australasian Association for the Advancement of Science, in which he described the results of a survey made by himself and his colleague, Mr. A. Gibb Maitland, with the object of defining the intake beds of the Artesian basin. He described some deposits of an exceedingly porous marine sandstone, which he named the *Blythesdale Braystones*, and which form the basal beds of the Lower Cretaceous system. It absorbs water with avidity, and is, moreover, so destitute of cementing material, that a lump of it, on being saturated with water, falls away to a heap of sand. Mr. Jack announced that the Blythesdale Braystones outcrop at the southern boundary of Queensland, to the west of the township of Texas, and extend, though not uninterruptedly, in a N.N.W. direction through Roma, and thence onward to near the Gulf of Carpentaria. He gave it as his opinion that the Blythesdale Braystones form the true intake beds of the Artesian water, and he made use of the following words :—" It is now well known that all our Artesian water, with trifling exceptions, occurs in the Rolling Downs or Lower Cretaceous Formation."

During the same year, however, in which Mr. Jack's paper was read, unquestionable evidence was obtained to prove that several of the most successful bores in New South Wales derived their water from the porous rocks of the Triassic Coal Measures, which underlie the Lower Cretaceous Formation. Fossil plant remains characteristic of the Triassic Coal Measures were recognised in fragments of rock obtained from the Moree and Coonamble bores,* and from the similarity of the drillings obtained in these bores and others in the western plains of the Colony there can be no doubt that, so far as New South Wales, at any rate, is concerned, the Triassic Coal Measures are the chief source of the Artesian water. The Blythesdale Braystones, so far as is at present known, do not outcrop in this Colony, and have not been intersected in any of our bores, and this suggests the probability that they may be a littoral deposit, formed along the north-eastern shore of the Cretaceous sea, and that may not extend far in the direction of their dip.

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* "On the occurrence of Artesian water in rocks other than Cretaceous," by E. F. Pittman. *Journ. R. Soc. N.S. Wales for* 1895, XXIX, pp. 408-415.

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Moreover, the Roma (Queensland) Artesian well must, it is believed, have derived its water from the Triassic rocks, as its depth would, in all probability, bring it below the horizon of the Blythesdale Braystones, which outcrop only a few miles to the east of Roma. The railway between Roma and Toowomba runs for a distance of about 200 miles across the strike of the Triassic sandstones, and in all probability the area of country between these two places, and extending southwards to the New South Wales border, will be found when tested to be Artesian water bearing, though it is all outside the limits of the Lower Cretaceous basin.

The possibility of the occurrence of Artesian water in rocks of this age was first alluded to in the Annual Report of the Department of Mines for 1880, page 244, as the following extract will show:—"As the rocks dip from all sides towards Grafton as a centre, I am of opinion that if a bore were put down there it would thoroughly test the district for coal, and would also be of great interest as a means of prospecting for Artesian water, the water supply of Grafton being a subject which is engrossing much attention just now."*

The geological structure of the New South Wales portion of the Great Australian Artesian basin is shown in the accompanying cross-section from east to west. The intake beds consist of porous sandstones belonging to the Triassic Coal Measures, and containing the characteristic fossil plants *Tæniopteris Daintreei* and *Thinnfeldia odontopteroides.* As will be seen by referring to the Mineral Map at the end of the volume, they extend† from the neighbourhood of Dubbo in a N.N.E. direction to the Queensland border, where their most easterly outcrop can be seen in the banks of the Sovereign River, about fifteen miles west of the township of Texas. This outcrop is shown on the Queensland geological maps as "Blythesdale Braystone"; but there is very little doubt, in view of its lithological characters, that it is in reality Triassic sandstone, and fossils typical of the latter rock have been identified not very far to the south-west of this outcrop.

These intake beds outcrop on the western flanks of the Dividing Range, resting unconformably on Carboniferous claystones or Silurian slates in some localities, while in others the underlying rock is granite. They occupy elevations of 1,200 feet or more above sea-level, and they occur, in the foothills of the range, for an average width of about 60 miles. The beds have a gentle dip to the westward, and they probably extend continuously underneath the western plains of New South Wales, within the limits of the Artesian area shown on the Mineral Map already referred to. Between Texas and Yetman the sandstones are very porous, and their disintegration by atmospheric influences has resulted in the covering of the surface with a deep deposit of sand, which must rapidly absorb the rain-water that falls upon it. The bores

*Geological Report on the Basins of the Clarence, Richmond, Brunswick, and Tweed Rivers, by E. F. Pittman.

† The area occupied by these rocks has not yet been accurately surveyed, and its representation on the map must be regarded as approximate only.

put down on the plains, to the west of the intake beds, have intersected numerous beds of bluish-gray shales intercalated with the sandstones, and several seams of coal have also been penetrated. The total thickness of the Triassic Coal Measures in this portion of the basin is probably about 2,500 feet.

(3.) *The Overlaying Formations.*—The Triassic Coal Measures are overlaid, in ascending order, by the Lower Cretaceous or Rolling Downs formation, the Upper Cretaceous or Desert Sandstones, and deposits of Pleistocene and Recent age consisting of "Red Soil," "Black Soil," and "Sandhills and Claypans."

The Lower Cretaceous rocks, which are typical of so much of the Western Queensland country, do not, so far as is at present known, show above the surface in this Colony, unless some thin beds of marl and shale, which are exposed in the bank of the Darling River at North Bourke, are referable to them. There must, however, be a considerable development of them in the northern portion of New South Wales underneath the superficial deposits of Pleistocene red soil and the black soil deposited by the flood waters of the Darling and its tributaries. Marine fossils of Lower Cretaceous age have been obtained in wells in the Mount Poole District, and it is probable that some of our shallowest Artesian bores, such as those on the Killara Station, and some others, may have derived their water from Lower Cretaceous rocks.

In the Moree District two deep bores were made by means of the Calyx drill, which has the great advantage of bringing up a solid core of the rocks penetrated; and an examination of these cores threw a considerable amount of light on the vexed question as to which are the true intake beds of the Artesian basin. One of the bores referred to was put down at Bulyeroi, about sixty miles W. by S. from Moree; and here, after passing through the black soil forming the surface of the plain, the drill penetrated Lower Cretaceous rocks (containing characteristic marine fossils) for a depth of 520 feet, below which shales, sandstones, and coal seams, with Triassic plant remains, were met with. At a depth of 175 feet, in the Cretaceous rocks, a very small supply of sub-artesian water was found; at 1,386 feet a flow of Artesian water, equal to 6,000 gallons per day, was met with, and the supply gradually increased as greater depth was attained, until at 2,370 feet it was estimated at 1,750,000 gallons per day.

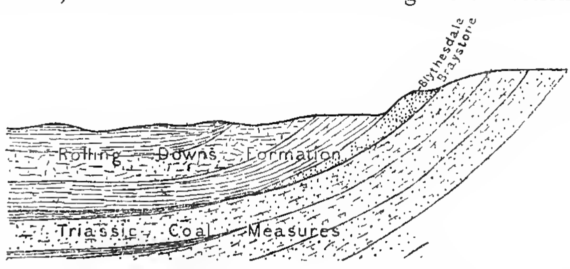
The Wallon bore is situated about twenty miles N. by W. from Moree, and the evidence supplied by it was quite as important as that just referred to. The Lower Cretaceous rocks were entered a short distance below the surface, and continued to a depth of 1,500 feet. They consisted of sandstones, shales, and marine limestones, and contained numerous bivalve shells, such as *Corimya*, *Maccoyella*, and *Pinna*. These rocks were succeeded in depth by the Triassic Coal Measures, containing characteristic plant remains. At 1,630 feet *Tæniopteris Daintreei* was recognised, and at 1,650 feet a coal seam, fifteen inches thick, was penetrated.* No water was obtained until a depth of 2,330 feet was reached, when a flow of 400 gallons per day was struck, and the yield continued to increase with the depth until, at 3,560 feet, it was estimated at 800,000 gallons per day. The bore was continued to 3,747 feet without any further addition to the flow.

What then becomes of the alleged importance of the Blythesdale Braystones, as the true intake beds of the Artesian basin, in view of the evidence of these bores? It may be as well to repeat that the Blythesdale Braystones form the lowest beds of the Lower Cretaceous formation, and they should, therefore, rest immediately on top of the Triassic Coal Measures. The cores from the Wallon and Bulyeroi bores prove either (1) that the Blythesdale Braystones do not extend as far as these localities, or (2) that they are not water-bearing there.

The first hypothesis is most likely the correct one, and there appear to be strong reasons for believing that the porous sandstones of Blythesdale, which have been traced for such a great distance meridionally, are a mere littoral deposit along the eastern margin of the old Cretaceous sea, and that they do not extend far in the direction of their dip before being overlapped by the marine limestones which succeed them. The Artesian water supply is undoubtedly contained in the Triassic Coal Measures, and the latter must form the true intake beds.

In the paper already quoted, Mr. Jack, the ex-Government Geologist of Queensland, stated that he had seen unmistakable evidence of unconformity between the Lower Cretaceous and Triassic formations, and that it was possible, in view of this unconformity, that porous rocks belonging to the latter might act as feeders to the water supplies of the Blythesdale Braystones. He illustrated his suggestion by a sketch section in which he represented the Coal Measures as thinning out beneath the Blythesdale Braystones.

The Wallon and Bulyeroi bores, however, show that the converse is much more likely to be the case; that the Blythesdale Braystones, in fact, may possibly play the less important role of feeders to the underlying Triassic Coal Measures, in accordance with the following sketch section:—




Moreover, there is no evidence of unconformity between the two series of rocks in the cores from Bulyeroi and Wallon. On the contrary,

* A section of the core of the Wallon bore is given at the end of the book.

the Coal Measures appear to be continuous under the New South Wales basin, which is nearly 600 miles in width, and this makes any unconformability very improbable. It is possible that the unconformity noticed in Queensland by Mr. Jack was merely local, and may have been due to contemporaneous erosion.

It seems more probable that the Lower Cretaceous rocks and the Triassic Coal Measures form portions of a continuous series, and that they succeeded one another regularly without any marked break; that the depression in which they were laid down was subject to alternations of elevation and subsidence, so that it became by turns a freshwater lake or an inland sea, and these changes of level extended well into Cretaceous times, for we find, in the Lower Cretaceous series, beds of marine limestones intercalated with sandstones, shales, and even impure coal.

Another interesting fact proved by the two bores just alluded to is that the Cretaceous rocks dip rapidly to the northwards from Bulyeroi, and there must have been very deep water to the north of Moree when these rocks were being laid down.

*The Upper Cretaceous Rocks.*—After the close of the Lower Cretaceous period there must have been a still further subsidence of the floor of the basin, for the desert sandstones, which are of marine origin are distributed over a much wider area than the earlier Mesozoic rocks. In New South Wales they occur as far south as Bidura, near Balranald, and they have been recognised in many other places outside the limits of the Artesian basin. They have, however, suffered to an enormous extent from denudation, and are generally seen as small hills, forming isolated outliers of what was once a continuous far-reaching deposit.

The desert sandstones are well represented in the neighbourhood of Mount Oxley, Milparinka, Mount Poole, Mount Stuart, and the Gray ranges to the north of the latter. There are two typical varieties of rock to be seen in these localities. One is a soft grayish white sandstone, passing in places into a coarse grit, while the other is an intensely hard but brittle porcelainised rock, which has the appearance of having originally been a porous grit, but which has been indurated by having all the interstices between the sand grains filled with secondary silica, which gives it a very opaline appearance when examined under a lens. One of the peculiarities of this rock is the manner in which it breaks up on the hill tops. The intense heat of the sun in summer raises the rock to a high temperature, and when this is followed by the sudden cooling effect of a thunderstorm, the large blocks of stone exfoliate and break up rapidly; it is consequently somewhat rare to see an outcrop of solid beds—the summits of the hills being covered with a rough shingle, which is so characteristic of Sturt's Stony Desert, in the neighbourhood of Milparinka and Mount Poole. This rock rings like porcelain when struck, and breaks with a conchoidal fracture. There seems to be very little doubt that it was originally identical with the softer variety of sandstone, and that the metamorphism has been caused by the action of thermal springs which deposited silica between the sand grains.

The desert sandstone occurs in this district in isolated ranges or hills, which, as a rule, have steep escarpments. The beds are generally horizontal or dip at a low angle, and are traversed by vertical joints. Near the top of the series there is a bed of conglomerate, a few inches thick, consisting of pebbles of an infinite variety of colour, and owing to the breaking up of this conglomerate by weathering, the lower ground is, in many places, strewn with highly polished pebbles of banded agate, chalcedony, jasper, carnelian, pink and white quartz, &c. The extremely high polish which these stones exhibit may possibly be due to the action of the wind and sand.

Occasionally highly ferruginous beds of desert sandstone are met with, to the disintegration of which the red sandy soil, which covers large areas of the plains, is probably due. Intercalated with the Desert Sandstones there are frequently seen beds of soft white rock which has very much the appearance of kaolin; and which is often mistaken for the latter; it consists, however, of nearly pure silica in an extremely fine state. It has been carefully examined under the microscope; but it has not been found to contain any organisms. Precious opal is found in rock of this character at White Cliffs in the Wilcannia District.

*Sandhills and Claypans.* Very large tracts of the north-western district are covered by peculiar deposits constituting what are known as "Sandhills and Claypans," and as these form quite a notable feature in the character of the artesian water area, they are perhaps worthy of a brief description. They are extensively developed along the road from Wanaaring to Milparinka, particularly between the Clifton bore and the last named town. The sandhills, which vary from small mounds to hills fifty feet in height are formed of blown sand; in many cases their surfaces are being continually modified by the action of the wind, and, as can be easily imagined, they make the tracks exceedingly heavy for travellers. There can be no doubt that the sand of which these hills are formed is due to the disintegration, in Post-Tertiary times, of the Upper Cretaceous or Desert Sandstones. The claypans, which are invariably met with in proximity to the sandhills, are shallow, flat-bottomed depressions; they vary in depth from a few inches to about three feet, and their floors consist of a thin bed of fine clay, upon which the water lies for a considerable time after rain. They are often quite circular in shape, while, in other instances, they form long channels of regular width. For miles and miles nothing is visible but a continuous succession of sandhills and claypans; the effect is desolate in the extreme, and the country is utterly useless for any purpose.

There has been much speculation as to the origin of these remarkable depressions, whose shape is often so regular as almost to suggest that they must have been artificial. It seems probable that they have been formed by the whirlwinds (the *Burramugga* of the aborigines) which are of very common occurrence in this country. Some of these whirlwinds remain stationary for a considerable time (forming columns of whirling sand sometimes a quarter of a mile high) which suggests the formation of the circular depressions—while a travelling whirlwind, such as is frequently met with, might be expected to sweep up the sand in such a manner as to form one of the long narrow channels. The depressions having thus been formed, subsequent rains would carry into them, in a state of suspension, fine clay washed out of the surrounding sandy soil. When the water was afterwards evaporated by the heat of the sun, or had sunk into the floor of the depression, a coating of clay would be left, and frequent repetitions of this process would leave a fairly thick bed of impervious clay.

Other Post-Tertiary deposits which form surfaces features of the Artesian area are the red and the black soils of the western plains, and so distinctive are they that "red soil country" and "black soil country" are descriptive terms in frequent use by pastoralists and others.

The red soil is a Pleistocene deposit and has probably been derived from the disintegration of the ferruginous beds of Desert Sandstone at a time when the rainfall was much greater than it is at the present day. This soil is of a rather light sandy nature, and red colour. It produces fairly good grass and herbage with a moderate amount of rain, and is especially suitable for irrigation, owing to its porous character.

The black soil is of a more heavy and clayey nature. In the neighbourhood of Moree, and other parts of that district, it is largely made up of decomposed basalt, while lower down the Darling it is not so dark in colour and consists of silt brought down by the flood waters of the river from the eastern country and deposited on the wide plains bordering the Darling. With a fair amount of rain it is an exceedingly fertile soil —much more so than the red soil—but, owing to its stiff clayey nature, it is much more difficult to work. A fall of about half an inch of rain will make black soil country exceedingly difficult to travel over; the wheels of vehicles continue to collect the stiff greasy mud until they attain enormous dimensions, and add very materially to the weight of the load, while the horses have great difficulty in obtaining foothold, and speedily become exhausted. A speed of a mile an hour is considered fair progress over this country when the tracks are in such a condition. With a greater amount of rain the difficulties are not quite so great, but travelling in wet weather is always slow and attended with great discomfort on the black-soil country. When the sun and wind have dried the ground the tracks become excessively rough; the soil which has been ploughed up by the wheels and by the horses' hoofs hardens in great clods, and the surface does not become smooth again until there has been a considerable amount of traffic over it.

*Mud Springs.*—An account of the Artesian basin would be incomplete without a reference to the peculiar occurrences known as Mud Springs. They are the visible evidence of the efforts of the water, stored

*Photographed by E. F. Pittman.*

TENANDRA ARTESIAN BORE, NEAR WARREN.

Depth of Bore, 1,038 feet. Flow, 1,000,000 gallons per day.

underground in a state of pressure, to force its way through the Cretaceous shales to the surface; in other words, they are natural Artesian wells. They consist of mounds of yellow clay mixed with water-worn pebbles, and in outward appearance they are not unlike large ant-hills; in the centre of each is a vertical pipe through which water, or rather liquid mud comes to the surface. The mounds have been formed by the very slow overflowing of the liquid mud, and, as some of them are of very large dimensions, they must have been forming for a very long period. They vary from a few feet up to fifty feet or more in diameter, and to ten or fifteen feet in height. They generally occur in groups, and it is noticeable that they are always within a short distance of the margin of the Artesian basin, or near the edge of some of the isolated patches of older rocks which once formed islands in the ancient Cretaceous sea. They may, therefore, be regarded as evidence that small flows of Artesian water will be obtained at shallow depths in their vicinity. Examples of these Mud Springs can be seen on Killara Station, at Yantabulla, on the Bourke to Hungerford road, and about seventeen miles to the north of Coolabah railway station.

*Physiography of the New South Wales Artesian Area.*—The vast plain, which stretches westwards from the base of the ranges forming the intake beds to the borders of South Australia, has a mean length of about 450 miles from east to west, by a mean width of about 130 miles from north to south. Its altitude varies from 200 to 700 feet above sea level, while the intake beds on its eastern boundary rise to altitudes of 1,200 feet or more.

The plain is drained by the Darling, while a number of the tributaries of that river have eroded their valleys through the intake beds or Triassic Coal Measures. The principal tributaries which cross the intake beds are the Sovereign or Dumaresq, the MacIntyre, the Gwydir, the Namoi, the Castlereagh, and the Macquarie.

The mean annual rainfall of the great plain varies from nine and three-quarter inches in the extreme west to eighteen inches near the base of the ranges, while on the intake beds the average rainfall is about twenty-five inches per annum according to the Government Astronomer's reports. The area of the intake beds is, approximately, 18,000 square miles, and they would, therefore, receive during an average year, a total rainfall equal to 1,045,440,000,000 cubic feet.

It is impossible to say, with any measure of accuracy, what proportion of this water would be absorbed by the intake beds. Mr. Russell has asserted that, of all the rain which falls within the *catchment area* of the Darling, only $1\frac{1}{2}$ per cent. passes through the channel of the river at Bourke; other writers have hazarded the opinion that about 50 per cent. is lost by evaporation. Assuming that both these estimates are correct (though the latter one is probably too high) there remain $48\frac{1}{2}$ per cent. to be accounted for by absorption. As showing the wonderful porosity of some rocks, the following remarks by Mr. James Tolson* may be quoted; the locality referred to is in Queensland:—

"I have seen 10 inches of rain fall within 24 hours on the high desert country between Uanda and the Cape River Gold-field, and not a drop run off the surface, the whole of it having been absorbed by the porous formation. I have also ridden through Torrens Creek after its being uncrossable for a week at the Lammermoor crossing, and with a width of 70 yards, when the water was well above the saddle-flaps, and 40 miles lower down on the same day the stream was not more than 30 yards wide, and not up to the horse's knees." Mr. R. L. Jack, in referring to these statements, remarks that the first locality mentioned is on the Desert Sandstone formation, while the second is on the Blythesdale beds; now, while the Blythesdale Braystones are perhaps more porous than our Triassic Coal Measures, the latter appear to be quite as absorbent as the Desert Sandstones.

It must be remembered that the six principal tributaries of the Darling, which have already been mentioned, have eroded their channels through the porous rocks of the Triassic Coal Measures, and therefore a very considerable proportion of the water passing down them must be absorbed by the rocks forming their beds. Several of these rivers, notably the Macquarie, never reach the Darling except in flood time, and it seems more than probable that this is mainly owing to the amount of water which is absorbed by their porous beds during its passage westwards.

Besides the water thus accounted for, a great quantity must be lost in its passage down the creeks which feed these rivers, and still more rain must be absorbed where it falls on the hillsides.

While any attempt to estimate the quantity actually absorbed must necessarily be speculative, a calculation, based on what may be supposed to be a low estimate, may be of interest. Assuming, therefore, that only 20 per cent. of the total annual rainfall on these intake beds is absorbed by them, we find that the available supply of water in the New South Wales Artesian basin would amount to 3,580,273,972 gallons per day, or more than forty-six times as much as is, at present, being obtained from the 158 bores already put down. This enormous supply of water is believed to be leaking into the ocean, and, indeed, this must be the manner of its escape, otherwise there would be an overflow on the land. In any case there does not appear to be much reason to fear that our Artesian bores will overtake the supply for many years to come.

There has already been some doubt expressed in regard to this question of overdrawing the supply, and this was occasioned by a marked falling off in the yield of the Pera Bore, near Bourke. This bore, when first constructed, had a flow estimated at 610,000 gallons per day, at a depth of 1,154 feet, but last year the yield was found to have diminished

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* *Australian Pastoralists' Review*, 15th December, 1892, p. 969.

*Photographed by E. F. Pittman.*

THE DROUGHT-STRICKEN WEST.

Orchard irrigated with artesian water at the Pera Bore, near Bourke.

to 300,000 gallons per day. It was found that through not being properly lined, the sides had caved in to some extent, and the decrease was at first attributed to this cause; however, the bore, on being cleaned out, yielded no increase, and a second bore was then put down near the first, but the flow obtained in this instance only amounted to 250,000 gallons per diem.

The real reason for the diminished flow is probably to be found in the protracted drought which had visited the Colony. If it be admitted that the source of the Artesian water is the rain which falls upon the porous intake beds, and percolates through these beds to the bottom of the basin, it cannot surely be doubted that a drought of four years' duration over the area of the intake beds must seriously affect the flow of water in the Artesian wells. Until more systematic measurements o Artesian flows are made, it would be impossible to ascertain how long a time would elapse before a drought over the intake beds would noticeably affect a bore two hundred miles to the west of them; but seeing that the drought in this case had lasted between three and four years when the diminished flow was observed, there cannot be much doubt as to the cause of the deficiency.

Several experiments in irrigation with Artesian water have been undertaken by the Government with the object of demonstrating to settlers the fertility of the western country under favourable conditions, and the success obtained has been all that could be desired.

The first experiment was made at the Native Dog bore, forty-five miles from Bourke, on the Barringun road. An area of twenty acres of land was enclosed, ploughed, ditched, and planted with an assortment of forest-trees, fruit-trees, cereals, and vegetables, while wheat, with two waterings, yielded at the rate of thirty-five bushels per acre.

In the year 1895, a block of 640 acres of land, in proximity to the Pera bore (seven miles from Bourke) was graded and subdivided into twenty-acre blocks, which were thrown open to homestead selectors, while the Government reserved sixty-eight acres for experimental purpose. Great success was obtained here also with all kinds of vegetables, and such fruit as peaches, apricots, prunes, figs, melons, almonds, oranges, lemons, and grapes; lucerne was found to grow luxuriantly, and so also were wheat, Kaffir corn, tares, buckwheat, sorghum, millet, &c.

Notwithstanding this wonderful object lesson, showing what can be done by irrigating the desert lands with Artesian water, it cannot be said that there has been much evidence of a desire on the part of the people to establish similar agricultural settlements. It is, doubtless, only a matter of time, however, and in the future the fruit-growing and canning industry should make great headway in this country where the climate and soil are both most suitable and water can be obtained in practically unlimited quantities from Artesian bores. There is a considerable trade in Australia in imported (Californian) fruits, and there is no reason why the demand should not be supplied by the colonial grown article.

*Quality of the Artesian Water.*—A large number of analyses of water from various bores has been made by Mr. J. C. H. Mingaye, in the Laboratory of the Department of Mines, and in a majority of cases these show that the proportion of mineral salts in the water is well under the maximum which renders a water unfit for human consumption, while the presence of an appreciable quantity of potash makes most of them especially suitable for irrigation purposes. The water as it issues from the bores has a rather strong odour of sulphuretted hydrogen, but after standing for some time it becomes perfectly inodorous. A list of analyses of different bore waters is appended.

List of Government Bores for Artesian Water, New South Wales.

| Bore. | Road. | Depth in ft. | Flow in gals. per diem. | Temperature. (°Fah.) | Pressure lb. to sq. in. | Remarks. |
|---|---|---|---|---|---|---|
| Bourke ... | Bourke Trucking Yards. | 1,467 | ........ | ... | ... | Failure. |
| Gidgia Camp... | Bourke to Barringun | 2,002 | 7,000 | 91 | 10 | Flowing. |
| Native Dog ... | do do... | 457 | 150,000 | 115 | ... | do |
| Enngonia ... | do do... | 1,666 | 320,000 | 117 | 165 | do |
| Belalie ... | do do... | 1,565 | 400,000 | 117 | 187 | do |
| Barringun ... | do do... | 1,711 | 170,000 | 115 | ... | Now 70,000 gallons. |
| Brigalow ... | Ledknapper to Culgoa River. | 2,292 | 150,000 | 90 | ... | Flowing. |
| Old Gnomery... | Culgoa River ... | 2,576 | 1,046,000 | 126 | ... | do |
| Walkdens ... | Bourke to Hungerford | 1,604 | 200,000 | ... | 62 | do |
| Kelly's Camp... | do do... | 1,577 | 600,000 | 112 | 80 | do |
| Kerribree ... | do do... | 1,193 | 800,000 | 111 | 92 | do |
| Youngerrina ... | do do... | 165 | 120,000 | 82 | 20 | do |
| Yantabulla 1... | do do... | 209 | 4,000 | 90 | ... | do |
| ,, 2... | do do... | 587 | 17,200 | 84 | ... | do |
| Kenmare ... | do do... | 1,539 | 2,050,000 | 115 | ... | do |
| Brindingabba.. | do do... | 1,241 | 70,000 | 100 | ... | do |
| Waroo ... | do do... | 385 | 17,000 | 88 | 36 | Flowing. |
| Berawinnia ... | Hungerford do... | 855 | ........ | ... | ... | Failure. |
| Pera No. 1 ... | Bourke to Wanaaring | 1,154 | 300,000 | 98 | 58 | Flowing. |
| Pera No. 2 .. | do do... | 1,569 | 250,000 | ... | ... | do |
| Sibraas ... | do do... | 1,059 | 700,000 | 98 | 62 | do |
| Poison Point... | do do.. | 1,399 | 20,000 | ... | ... | do |
| Goonery ... | do do... | 120 | 1,000 | ... | ... | do |
| Dargle ... | do do... | 1,179 | 50,400 | 92 | ... | do |
| Tincbelooka ... | do do... | 1,231 | 52,000 | 98 | ... | do |
| Kulkyne ... | do do... | 1,781 | 5,000 | ... | ... | do |
| Cuttaburra ... | do do... | 1,707 | 20,000 | 96 | ... | do |
| Wanaaring ... | do do... | 1,644 | 400,000 | 116 | 10 | do |
| Mulgany ... | Wanaaring to Milparinka. | 1,700 | 30,000 | 105 | ... | Pumping supply. |
| Currabulla ... | do do... | 1,973 | 50,000 | 96 | ... | do |
| Ninety-one-mile .. | do do... | 2,002 | 50,000 | ... | ... | do |

| Bore. | Road. | Depth in ft. | Flow in gals. per diem. | Temperature. (°Fah.) | Pressure lb. to sq. in. | Remarks. |
|---|---|---|---|---|---|---|
| Osacca ... | Wanaaring to Milparinka. | 1,646 | 350,000 | 129 | ... | Ceased flowing, being choked. |
| Clifton ... | do do... | 1,638 | 1,500,000 | 139 | ... | Flowing. |
| Tinaroo ... | do do... | 1,858 | 800,000 | 139 | ... | do |
| Warratta ... | do do... | 2,393 | ......... | ... | ... | Pumping supply. |
| Opera ... ... | Louth to Wanaaring | 803 | 50,000 | ... | ... | do |
| Barrona ... | do do... | 1,010 | 200,000 | 100 | ... | Flowing. |
| Quarry Reserve | Bourke to Cobar ... | 1,391 | ......... | ... | .. | Failure. |
| Moree ... | Moree ... ... | 2,792 | 1,108,080 | 115 | 94 | Flowing. |
| Woolabra ... | Moree to Narrabri.. | 1,988 | 500,000 | 90 | ... | do. |
| Wallon ... | Moree to Boggabilla. (New Road). | 3,747 | 800,000 | 124 | .. | do. |
| Careunga ... | do do... | 2,731 | 6,000 | ... | ... | In progress. |
| Dolgelly ... | do do... | 4,086 | 745,200 | 130 | ... | Flowing. |
| Gil Gil ... | Moree to Boggabilla (Old Road). | 3,093 | 700,000 | 112 | ... | do |
| Tulloona ... | do do.. | 3,537 | 783,000 | 120 | ... | do |
| Bulyeroi ... | Bulyeroi to Collarendabri. | 2,424 | 1,750,000 | 116 | ... | do |
| Mercadool ... | Near Collarendabri.. | 1,872 | 1,160,225 | 119 | ... | In progress. |
| Moongulla ... | Collarendabri to Angledool. | 2,570 | 557,735 | 125 | 88 | Flowing. |
| Dungle Ridge.. | do do... | 2,566 | 850,000 | 122 | ... | do |
| Eurie Eurie ... | Narrabri to Walgett | 2,721 | 2,000,000 | ... | ... | do |
| Moramina ... | Walgett to Goodooga | 2,271 | 1,069,200 | 107 | ... | do |
| Wilby Wilby.. | do do... | 2,162 | 1,114,800 | 115 | ... | do |
| Goodooga ... | Goodooga ... ... | 2,812 | 432,000 | 120 | ... | do |
| Finger Post ... | Goodooga to Angledool. | 3,144 | 750,000 | 125 | ... | do |
| Tooloora ... | Walgett to Coonamble. | 1,543 | 1,738,800 | 104 | 126 | do |
| Coonamble ... | Coonamble ... ... | 1,302 | 1,878,000 | 95 | 85 | do |
| Bourbah ... | Bourbah ... ... | 1,797 | 1,134,000 | 95 | ... | do |
| Gilgandra ... | Gilgandra ... ... | 3,035 | 2,000 | ... | ... | do |
| Tenandra ... | Coonamble to Warren. | 1,036 | 1,000,000 | ... | ... | do |
| Warren ... | Warren ... ... | 869 | 1,000,000 | 70 | 25 | do |
| Nevertire . | Nevertire ... ... | 2,524 | ......... | ... | ... | Pumping supply. |
| Nyngan ... | Nyngan ... ... | 710 | 11,000 | ... | ... | do |
| Green Camp ... | Nyngan to Warren.. | 1,327 | ......... | ... | ... | do |
| Collie ... ... | Collie ... ... | 821 | ......... | ... | ... | In progress. |
| Trangie ... | Trangie ... ... | 1,021 | ......... | ... | ... | Pumping supply. |
| Coolabah ... | Coolabah ... ... | 781 | 14,000 | ... | ... | Flowing. |
| Whitewood ... | Brewarrina to Goodooga. | 1,240 | ......... | ... | .. | Failure. |
| Bendermere ... | Brewarrina to Gongolgon. | 1,726 | ......... | ... | ... | do |

| Bore. | Road. | Depth in ft. | Flow in gals. per diem. | Temperature. (°Fah.) | Pressure lb. to sq. in. | Remarks. |
|---|---|---|---|---|---|---|
| Narrowin ... | Brewarrina to Nyngan .. | 1,179 | 6,000 | ... | ... | Flowing. |
| Ginghet ... | Near Carinda ... | 1,319 | 1,000,000 | 90 | ... | do |
| Carinda ... | Carinda ... .. | 1,702 | 1,000,000 | 102 | ... | do |
| Paldrumata ... | Wilcannia to Wampah .. | 780 | ......... | ... | ... | Pumping supply |
| Ooarnoo ... | do do... | 1,359 | ...... ... | ... | ... | do |
| Warri Warri... | do do... | 3,100 | ......... | ... | ... | In progress. |
| Packsaddle ... | Cobham to Silverton | 1,942 | 50,000 | ... | ... | Pumping supply |
| Bancanya ... | do do... | 3,615 | ........ | ... | ... | do |
| Sandy Creek... | do do... | 678 | 50,000 | ... | ... | do |
| Hay ... ... | Hay ... ... ... | 1,962 | ......... | ... | ... | do |
| Dolmoreve .. | Balranald to Ivanhoe | 1,237 | ......... | ... | ... | do |
| Holey Box ... | Mossgiel to Ivanhoe. | 1,230 | ......... | ... | ... | Failure. |
| Tolarno ... | Menindie to Ivanhoe | 1,602 | 50,000 | ... | ... | Pumping supply |
| Toorincaca ... | Do | 1,488 | ......... | ... | ... | do |
| Arumpo ... | Box Creek to Arumpo | 1,850 | ......... | ... | ... | Failure. |
| Finley... ... | Finley ... ... | 421 | ......... | ... | ... | do |
| Grafton ... | Grafton ... .. | 3,125 | ......... | ... | ... | In progress. |
| Tuon ... ... | *Via* Bourke ... ... | 1,790 | 1,000,000 | 120 | ... | Flowing. |
| Tuncoona ... | Do ... ... | 1,081 | ......... | ... | ... | In progress. |
| Curragh ... | Do ... ... | 786 | 28,000 | ... | ... | Flowing. |
| Artesia ... | *Via* Bourke ... ... | 1,201 | 70,000 | ... | ... | do |

## List of Private Artesian Bores in New South Wales.

| Bore. | No. | Depth in feet. | Flow in gals. per diem. | Temperature. (° Fah.) | Remarks. |
|---|---|---|---|---|---|
| Lissington... .. ... | 1 | 1,400 | 100,000 | 116 | |
| Do ... ... ... | 2 | 1,130 | 50,000 | 100 | |
| Do ... ... ... | 3 | 1,070 | 3,000,000 | 99 | |
| Do ... ... ... | 4 | 1,207 | 4,000,000 | 104 | |
| Talowonta ... ... | 1 | 1,949 | 40,000 | ...... | Very cool. |
| Wangamana ... ... | 1 | 1,600 | 7,200 | ...... | Flow decreasing. |
| Urisino ... ... ... | 1 | 1,680 | ......... | 120 | Pumping supply. |
| Do ... ... ... | 2 | 1,755 | ......... | 120 | do |
| Do ... ... ... | 3 | 1,475 | ......... | 120 | do |
| Warraweena ... ... | 1 | 1,247 | 196,000 | 96 | |
| Do ... ... ... | 2 | 840 | 40,000 | 90 | |
| Do ... ... ... | 3 | 997 | 35,000 | 90 | |
| Brindingabba ... ... | 1 | 760 | 250,000 | 90 | |
| Do ... ... ... | 2 | 820 | 480,000 | 90 | |
| Do ... .. ... | 3 | 1,114 | 385,000 | 112 | |
| Do ... ... .. | 4 | 1,170 | 35,000 | 100 | |
| Dunumbral ... ... | 1 | 2,480 | ......... | ...... | Abandoned. |
| Cuttabulla (Lila Springs).. | 1 | 1,357 | 30,000 | 80 | |
| Do ... | 2 | 2,001 | 72,000 | 104 | |
| Do ... | 3 | 1,729 | 4,000,000 | 121 | |
| Glengarie ... ... ... | 1 | 1,369 | 250,000 | ..... | |
| Elsinore ... ... ... | 1 | 1,770 | 85,000 | 122 | Pumping supply. |
| Do ... ... ... | 2 | 1,757 | 1,000,000 | 135 | Flowing. |
| Wapwelah ... ... | 1 | 720 | 8,000 | 80 | |

| Bore. | No. | Depth in feet. | Flow in gals. per diem. | Temperature. (° Fah.) | Remarks. |
|---|---|---|---|---|---|
| Wapwelah ... ... | 2 | 1,407 | 57,600 | 114 | |
| Dunlop ... .. ... | 1 | 820 | 50,000 | ...... | Salt. |
| Do ... ... ... | 2 | 940 | 600,000 | ...... | |
| Do ... ... ... | 3 | 860 | 600,000 | ...... | |
| Do ... ... ... | 4 | 750 | 500,000 | ...... | |
| Do .. ... ... | 5 | 900 | 5,000 | ...... | Now ceased flowing. |
| Do ... ... ... | 6 | 650 | ......... | ...... | Pumping supply. |
| Do ... ... ... | 7 | 576 | ......... | ...... | Failure. |
| Do ... ... ... | 8 | 883 | 150,000 | ...... | |
| Do ... ... ... | 9 | 800 | 500,000 | ...... | |
| Do ... ... ... | 10 | 1,100 | 250,000 | ...... | |
| Do ... ... ... | 11 | 816 | 11,000 | ...... | |
| Do ... ... ... | 12 | 948 | 13,000 | ...... | |
| Do ... ... ... | 13 | 823 | 15,000 | ...... | |
| Do ... ... ... | 14 | 703 | 13,000 | ...... | |
| Do ... ... ... | 15 | 751 | ......... | ...... | Failure. |
| Do ... ... ... | 16 | ...... | ......... | ...... | In progress. |
| Do ... ... ... | 17 | 1,200 | 15,000 | ...... | |
| Yancannia ... ... | 1 | 225 | 200,000 | ...... | |
| Do ... ... | 2 | 850 | ......... | ...... | Pumping supply. |
| Do ... ... | 3 | 659 | ......... | ...... | Failure. |
| Do ... ... | 4 | 727 | 100,000 | ...... | |
| Do ... ... | 5 | 962 | 200,000 | ...... | |
| Do ... ... | 6 | 917 | 255,000 | ...... | |
| Bangate ... ... ... | 1 | 2,387 | 1,360,000 | ...... | |
| Tinapagi ... ... ... | 1 | 963 | 13,600 | ...... | |
| Do ... ... ... | 2 | 533 | ......... | ...... | do |
| Do ... ... ... | 3 | 1,243 | 75,000 | ...... | |
| Boorooma ... ... ... | ... | 1,493 | ......... | ...... | do |
| Bootra ... ... ... | ... | 1,105 | 35,000 | ... | |
| Momba ... ... ... | 1 | 1,261 | ......... | ...... | Pumping supply. |
| Do ... ... ... | 2 | 1,947 | ......... | ...... | Failure. |
| Do ... ... ... | 3 | 1,997 | ......... | ...... | Pumping supply. |
| Do ... ... ... | 4 | 223 | 108,000 | ...... | |
| Do ... ... ... | 5 | 1,755 | ......... | ...... | Failure. |
| Goondabluie ... ... | 1 | 2,800 | 3,000,000 | 148 | |
| Do ... ... | 2 | 2,000 | ......... | ...... | Particulars not to hand. |
| Fort Bourke ... .. | 1 | 1,284 | 1,200,000 | 96 | |
| Do ... ... | 2 | 1,403 | 150,000 | ...... | |
| Belalie ... ... ... | 1 | 1,700 | 600,000 | ...... | |
| Do ... ... ... | 2 | 1,720 | 500,000 | 120 | |
| Do ... ... ... | 3 | 1,720 | 2,000,000 | 120 | |
| Pirillie ... ... ... | 1 | 839 | ......... | ...... | Failure. |
| Do ... ... ... | 2 | 645 | 44,000 | 95 | |
| Do ... ... ... | 3 | 630 | 18,000 | 95 | |
| Correlia ... ... ... | 1 | 943 | 368,000 | 96 | |
| Do ... ... ... | 2 | 1,112 | 156,000 | 92 | |
| Do ... ... ... | 3 | 1,327 | 240,000 | 102 | |
| Nocoleche ... ... ... | 1 | 916 | 140,000 | ...... | |
| Do ... .. ... | 2 | 1,500 | ......... | ...... | Pumping supply. |
| Do ... ... ... | 3 | 1,227 | 700,000 | ...... | |
| Wanaaring ... ... | 1 | 1,430 | 15,000 | 98 | |
| Do .. ... ... | 2 | 1,330 | 200,000 | 120 | |

| Bore. | No. | Depth in feet. | Flow in gals. per diem. | Temperature. (° Fah.) | Remarks. |
|---|---|---|---|---|---|
| Clifton Downs (Rushtons) | ... | 1,080 | 244,000 | 102 | |
| New Angledool ... ... | ... | 2,664 | 120,000 | 117 | |
| Salisbury Downs ... ... | 1 | 1,365 | 45,000 | ...... | Pumping supply. |
| Do ... ... | 2 | 1,568 | 55,000 | ...... | do |
| Do ... .. | 3 | 1,400 | 40,000 | ...... | do |
| Do ... ... | 4 | 1,338 | 60,000 | ...... | do |
| Do ... ... | 5 | 1,708 | ........ | ...... | Failure. |
| Toorale ... ... ... | 1 | 780 | 400,000 | ...... | |
| Do ... ... ... | 2 | 385 | 100,000 | ...... | Decreased to 30,000 gals. |
| Do ... ... ... | 3 | 2,300 | 30,000 | ...... | |
| Do ... ... ... | 4 | 1,485 | ......... | ...... | Pumping supply. |
| Do ... ... ... | 5 | 400 | 40,000 | ...... | |
| Do ... ... ... | 6 | 500 | 1,000 | | |
| Do ... ... ... | 7 | 1,700 | ......... | ...... | Failure. |
| Do ... ... ... | 8 | 900 | ......... | ...... | do |
| Do ... ... ... | 9 | 890 | ......... | ...... | do |
| Do ... ... ... | 10 | ... | ......... | ...... | In progress. |
| Buckanbe ... ... .. | ... | 725 | ......... | ..... | No flow. |
| Marra ... ... ... | 1 | 1,482 | ......... | ...... | Abandoned. |
| Do ... ... ... | 2 | 895 | ......... | ...... | Small supply. |
| Yanda ... ... ... | 1 | 750 | ......... | ...... | No flow. |
| Do ... ... ... | 2 | 1,008 | ......... | ...... | do |
| Weilmoringle ... ... | 1 | 2,005 | 28,000 | 90 | |
| Do ... ... | 2 | 1,590 | 1,728,000 | 113 | |
| Maranoa (Briwarra) ... | ... | 1,340 | 1,600,000 | 112 | |
| Toulby ... ... ... | 1 | 1,570 | 3,500,000 | ...... | |
| Do ... ... ... | 2 | 1,791 | 600,000 | ...... | |
| Kerribree ... ... ... | 1 | 1,073 | 350,000 | ...... | |
| Do ... ... ... | 2 | 1,340 | 1,000,000 | .. ... | |
| Kallara ... ... ... | 1 | 46 | 9,000 | 80 | |
| Do ... ... ... | 2 | 140 | 160,000 | 89 | |
| Do ... ... ... | 3 | 600 | 10,000 | 80 | Pumping supply. |
| Do ... .. .. | 4 | 820 | 1,000 | ...... | do |
| Do ... ... | 5 | 900 | 1,500 | ...... | do |
| Do ... ... ... | 6 | 1,411 | 2,000 | 90 | do |
| Do ... ... ... | 7 | 540 | 500,000 | 92 | |
| Do ... .. ... | 8 | 931 | 60,000 | 89 | do |
| Do ... . ... | 9 | 931 | 50,000 | ...... | do |
| Do ... ... ... | 10 | 700 | 7,000 | ...... | |
| Do ... ... | 11 | 900 | ......... | ...... | No flow. |
| Do .. ... ... | 12 | 463 | 8,000 | ...... | Flow. |
| Multagoona ... ... | 1 | 1,030 | 100,000 | ...... | |
| Do ... ... | 2 | 1,118 | 230,000 | ...... | |
| Morton Plains ... ... | ... | 1,855 | 600,000 | ...... | |
| Euroka ... ... ... | ... | 1,584 | 800,000 | 108 | |
| Butterbone ... ... | 1 | 921 | 1,000,000 | 88 | |
| Do ... ... | 2 | ... | ......... | ...... | Particulars not to hand. |
| Weemabung ... .. | ... | 1,010 | 1,500,000 | 86 | |
| Haddon Rig ... ... | 1 | ... | ......... | ..... | do |
| Do ... ... | 2 | ... | ......... | ...... | do |
| Thurloo Downs ... ... | ... | 2,150 | 2,000,000 | ...... | |

*Analyses of Artesian Bore Waters.*

The following analyses were made in the Laboratory of the Department of Mines by Mr. J. C. H. Mingaye, F.C.S.

| Name of Bore. | Total solid matter in grains per gallon. | $Na_2CO_3$. | $K_2CO_3$. | $CaCO_3$. | $MgCO_3$. | NaCl. | KCl. | $MgCl_2$. | $K_2SO_4$. | $Fe_2O_3$ and $Al_2O_3$. | $SiO_2$. | Organic matter. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bancanya | 253·60 | 47·47 | .... | 5·15 | 10·70 | 171·91 | .... | .... | ($Na_2SO_4$ 17·74) | ·21 | ·42 | trace. |
| Barringun | 39·11 | 23·93 | 6·10 | ·35 | .... | 6·74 | .... | .... | ...... | ·25 | 1·74 | trace. |
| Barrona | 148·37 | 7·95 | .... | 7·55 | ·99 | 78·17 | 52·51 | .... | ...... | .... | 1·20 | trace. |
| Belalie | 39·78 | 27·77 | 1·27 | ·65 | trace. | 7·91 | .... | .... | ...... | trace. | 1·26 | ·92 |
| Belalie No. 1 (private bore) | 43·45 | 33·99 | trace. | ·64 | trace. | 6·92 | .... | .... | ...... | ·11 | 1·79 | trace. |
| Belalie No. 2 (private bore) | 39·27 | 29·04 | trace. | 1·00 | ·32 | 6·70 | .... | .... | ...... | ·28 | 1·93 | trace. |
| Belalie No. 3 (private bore) | 33·12 | 24·31 | trace. | ·60 | ·10 | 6·57 | .... | .... | ...... | trace. | 1·54 | trace. |
| Boatman's | 34·15 | 17·74 | .... | ·89 | trace. | 11·12 | .... | .... | 3·16 | trace. | 1·23 | .... |
| Bourbah | 31·50 | 23·36 | .... | 1·12 | ·84 | 2·96 | trace. | .... | ...... | .... | 1·26 | trace. |
| Bourke | 34·30 | 20·94 | 2·95 | .... | trace. | 8·44 | .... | .... | ...... | trace. | 1·96 | trace. |
| Brigalow | 45·39 | 31·25 | 2·67 | ·91 | trace. | 7·65 | .... | .... | ...... | ·48 | 1·54 | ·88 |
| Bulyeroi | 54·71 | 45·32 | trace. | ·94 | .... | 6·27 | .... | .... | ...... | ·42 | 1·76 | trace. |
| Butterbone No. 1 (private bore) | 42·92 | 36·91 | trace. | ·90 | ·21 | 3·47 | .... | .... | ...... | trace. | 1·43 | .... |
| Butterbone No. 2 (private bore) | 36·98 | 31·47 | trace. | ·65 | ·21 | 3·23 | .... | .... | ...... | trace. | 1·43 | .... |
| Carinda | 57·31 | 42·53 | 2·38 | ·55 | trace. | 10·23 | .... | .... | ...... | ·22 | 1·40 | .... |
| Clifton | 125·83 | 98·18 | 1·64 | 1·70 | ·95 | 21·48 | .... | .... | ...... | ·16 | 1·71 | trace. |
| Coonamble | 53·06 | 40·00 | .... | 1·12 | trace. | 6·91 | .... | .... | ...... | .... | .... | .... |
| Corella No. 1 (private bore) | 46·34 | 27·81 | 7·17 | 1·00 | ·34 | 8·73 | .... | .... | ...... | trace. | 1·29 | trace. |
| Corella No. 2 (private bore) | 50·32 | .... | .... | ...... | .... | .... | .... | .... | ...... | .... | .... | .... |
| Corella No. 3 (private bore) | 56·87 | .... | .... | ...... | .... | .... | .... | .... | ...... | .... | .... | .... |
| Currabulla | 58·66 | 43·21 | ·94 | 1·50 | ·68 | 10·82 | .... | .... | ...... | trace. | 1·51 | trace. |
| Cuttaburra | 396·87 | 6·71 | .... | 6·66 | ·34 | 349·04 | trace. | 4·19 | ...... | ·11 | 1·60 | .... |
| Dolgelly | 45·77 | 33·82 | trace. | ·35 | trace. | 7·83 | .... | .... | ($Na_2SO_4$ 1·88) | traces. | 1·90 | .... |
| Dolmoreve (from shaft) | 164·14 | .... | .... | ...... | .... | .... | .... | .... | ...... | .... | .... | .... |
| Dolmoreve (well bore) | 163·63 | .... | .... | ...... | .... | .... | .... | .... | ...... | .... | .... | .... |
| Dungle Ridge | 80·09 | 52·56 | 6·94 | ·32 | 2·53 | 15·94 | .... | .... | ...... | .... | 1·79 | trace. |
| Enngonia | 47·65 | 30·37 | 4·74 | 1·20 | .... | 7·74 | .... | .... | ...... | trace. | 1·69 | 1·90 |
| Euroka (private bore) | 75·21 | 56·49 | .... | ·25 | trace. | 15·32 | .... | .... | 1·28 | .... | .... | .... |
| Fort Bourke (private bore) | 53·77 | 21·66 | 12·26 | 4·75 | ·04 | 9·72 | .... | .... | 1·25 | trace. | 4·09 | .... |
| Gidgia Camp | 47·57 | 30·71 | 3·35 | 1·30 | ·27 | 10·43 | .... | .... | ...... | ·17 | 1·34 | trace. |
| Gilgandra | 196·09 | 20·07 | trace. | 3·95 | 1·99 | 149·22 | .... | .... | 19·27 | ·42 | 1·18 | .... |
| Gil Gil | 43·98 | 32·63 | 1·70 | ·50 | ·13 | 7·26 | .... | .... | .... | trace. | 1·76 | trace. |

## Analyses of Artesian Bore Waters—*continued.*

| Name of Bore. | Total solid matter in grains per gallons. | $Na_2CO_3$. | $K_3CO_3$. | $CaCO^3$. | $MgCO_3$. | NaCl. | KCl. | $MgCl_2$. | $K_2SO_4$. | $Fe_2O_3$. and $Al_2O_3$. | $SiO_3$. | Organic matter. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Haddon Rig | 41·41 | 33·94 | trace. | ·75 | trace. | 5·73 | .... | .... | .... | trace. | ·98 | .... |
| Kelly's Camp | 35·08 | 16·87 | 5·67 | ·69 | trace. | 7·91 | .... | .... | .... | ·20 | 1·32 | 2·44 |
| Kenmare | 35·62 | 25·96 | trace. | 1·05 | trace. | 7·23 | .... | .... | .... | .... | 1·37 | .... |
| Kerribree | 34·35 | 17·60 | 6·38 | ·65 | .... | 7·74 | .... | .... | ...... | trace. | ·98 | 1·01 |
| Moongulla | 83·06 | 54·79 | 5·46 | ·80 | .... | 19·93 | .... | .... | ...... | .... | 2·07 | .... |
| Mooranina | 56·15 | 45·56 | trace. | 1·00 | ·38 | 7·25 | .... | .... | ...... | ·28 | 1·68 | .... |
| Moree | 49·78 | 39·26 | 1·10 | ·64 | ·29 | 7·03 | .... | .... | ...... | trace. | 1·46 | trace. |
| Morton Plains (1st supply) | 69·45 | 29·46 | trace. | 1·30 | ·72 | 35·96 | .... | .... | ...... | ·56 | 1·46 | .... |
| Morton Plains (2nd supply) | 43·57 | 34·20 | trace. | ·65 | trace. | 6·96 | .... | .... | ...... | trace. | 1·76 | .... |
| Mulgany | 51·71 | 37·60 | 2·37 | 1·15 | ·13 | 8·79 | .... | .... | ...... | trace. | 1·68 | trace. |
| Native Dog | 45·11 | .... | .... | ...... | .... | .... | .... | .... | ...... | .... | .... | .... |
| Nevertire | 119·56 | .... | .... | ...... | .... | .... | .... | .... | ...... | .... | .... | .... |
| Opera | 312·26 | .... | .... | 8·19 | .... | 278·38 | 12·27 | 6·58 | ($CaSO_4$ 5·84) | .... | 1·00 | tracc. |
| Osacca | 73·51 | 56·51 | 2·44 | ·90 | ·70 | 11·37 | .... | .... | ...... | trace. | 1·60 | trace. |
| Paldrumata | 357·64 | 19·75 | trace. | 6·10 | 8·90 | 321·30 | .... | .... | ...... | ·42 | 1·18 | .... |
| Pera | 45·07 | 33·12 | 1·22 | ·85 | ·40 | 7·69 | .... | .... | ...... | ·25 | 1·06 | ·47 |
| Poison Point | 296·63 | .... | .... | ...... | .... | .... | .... | .... | ...... | .... | .... | .... |
| Sandy Creek | 160·13 | .... | .... | ($CaSO_4$ 28·12) | 5·18 | 108·91 | 3·89 | 6·68 | ($MgSO_4$ 6·48) | ·28 | ·56 | .... |
| Sibraas | 70·11 | 24·05 | 8·29 | 2·80 | trace. | 30·32 | .... | .... | ...... | ·31 | 2·24 | 1·20 |
| Tinaroo | 205·91 | .... | .... | ...... | .... | .... | .... | .... | ...... | .... | .... | .... |
| Tinchclooka | 129·95 | 3·53 | .... | 6·65 | 1·51 | 66·07 | 50·82 | .... | ...... | .... | 1·37 | trace. |
| Tooloora | 60·33 | 45·56 | 5·58 | ·25 | ·29 | 6·72 | .... | .... | ...... | trace. | ·98 | ·95 |
| Tulloona | 42·50 | 30·27 | trace. | 30·27 | trace. | 8·10 | .... | .... | 2·17 | trace. | 1·44 | .... |
| Walkden's | 50·11 | 37·02 | 1·21 | 1·00 | ·25 | 9·29 | .... | .... | ...... | trace. | 1·33 | trace. |
| Wallon | 78·68 | 58·72 | trace. | ·75 | ·27 | 15·80 | .... | .... | ...... | ·22 | 2·91 | .... |
| Wanaaring | 50·63 | 35·79 | 1·23 | 1·30 | ·19 | 10·39 | .... | .... | ...... | trace. | 1·68 | trace. |
| Waroo | 35·79 | 19·21 | 4·56 | ·60 | ·61 | 8·40 | .... | .... | ...... | ·25 | 1·29 | ·87 |
| Warratta | 202·12 | 16·67 | .... | 3·05 | ·80 | 150·17 | 22·13 | .... | 6·90 | ·28 | 2·13 | trace. |
| Warren | 48·60 | 38·34 | trace. | 1·21 | ·26 | 7·23 | .... | .... | ...... | ·19 | 1·37 | .... |
| Weemabung (private bore) | 41·11 | 34·86 | trace. | ·60 | ·34 | 3·86 | .... | .... | ...... | trace. | 1·46 | .... |
| Woolabra | 44·17 | 21·57 | 3·26 | ·30 | ·19 | 6·05 | .... | .... | ...... | ·31 | 2·49 | .... |
| Yantabulla | 40·00 | 17·37 | 6·61 | 1·55 | ·93 | 9·56 | .... | .... | ...... | traces. | 1·46 | 2·52 |
| Youngerrina | 32·98 | .... | .... | ...... | .... | .... | .... | .... | ...... | .... | .... | .... |

DESCRIPTION of the core obtained in the Wallon Bore*, being a geological section of the Artesian Basin :—

| Depth in feet. | Description of Rocks. |
|---|---|
| 350 | Greenish shale, with comminuted plant fragments. |
| 400 | ,, ,, ,, |
| 450 | ,, ,, ,, |
| 500 | ,, ,, ,, |
| 515 | Shaley sandstone, with abundant plant fragments. |
| 530 | Shale, with abundant plant remains and coaly patches. |
| 570 | Greenish argillaceous sandstones, very friable. |
| 612 | Greenish argillaceous sandstones, fairly hard. |
| 620 | Argillaceous friable sandstones, with plant fragments. |
| 670 | Gray micaceous shale, with plant fragments. |
| 733 | Friable argillaceous green sandstone. |
| 750 | Shale, with carbonaceous matter. |
| 815 | Shale, with plant fragments, and alternating more sandy layers. |
| 850 | Carbonaceous shale. |
| 900 | Sandy micaceous shale, with plant fragments. |
| 950 | Dark shale, with shell fragments. |
| 1,000 | ,, ,, ,, |
| 1,050 | Dark shale. |
| 1,060 | Dark calcareous shale, not fissile, with calcite veins. |
| 1,104 | Nodular calcareous shale. |
| 1,150–5 | Calcareous shale, with *Cyprina* and *Pinna*. |
| 1,175 | Greenish sandy shale, with coal patches. |
| 1,200 | Dark calcareous shale, with marine shells. |
| 1,236 | Fissile micaceous shale. |
| 1,240 | Sandy shale, with shell fragments. |
| 1,290 | Calcareous shale, with *Maccoyella Barklyi*. |
| 1,275–1,310 | Fragments of shale, with carbonised and pyritised wood. |
| 1,310 | Hard calcareous shale. |
| 1,326 | ,, ,, |
| 1,375 | Sandy shale, with wood. |
| 1,400 | Sandy shale, with marine shells. |
| 1,450 | Micaceous shale, with plant fragments. |

* The first 1,800 feet were bored by means of the Calyx drill, and a solid core (which is now in the Geological Museum) was obtained. Below the depth mentioned a percussion drill was used. The fossils found in this core show that the Lower Cretaceous rocks overlie the Triassic Coal Measures. No water was obtained until a depth of 2,330 feet was reached, proving that the Triassic rocks (and not the Lower Cretaceous) are the source of the Artesian water.

| Depth in feet. | Description of Rocks. |
|---|---|
| 1,500 | Micaceous fissile shale, with sandy streaks. |
| 1,520 | Calcareous sandy shale, with nine inches of calcareous sandstone. Plant remains in shale. |
| 1,527 | Coal seam, five inches thick. |
| 1,535 | Argillaceous sandstone, fissile and micaceous, with abundant plant remains. |
| 1,570 | Dark carbonaceous shale. |
| 1,600 | Argillaceous sandstone. |
| 1,630 | Brown shale, with *Tæniopteris Daintreei.* |
| 1,650 | Coal seam, six inches thick. |
| 1,675 | Micaceous shale, with calcite veins. |
| 1,710 | Variegated shale, with plant fragments. |
| 1,719 | Shale, with abundant plant remains. |
| 1,750 | Micaceous sandy shale, with abundant plant remains. |
| 1,760 | Argillaceous calcareous sandstones, with *Tæniopteris Daintreei.* |
| 1,770 | Argillaceous sandstone. |
| 1,800 | Micaceous sandy shale, with carbonaceous streaks. |

# SUPPLEMENT.

## PRODUCTION OF METALS AND MINERALS FOR THE YEAR 1900.

| | Quantity. | Value. £ | s. | d. |
|---|---|---|---|---|
| ‡Alunite ... ... ... ... | 1,915 tons | 5,745 | 0 | 0 |
| ‡Antimony (metal and ore) ... | 191·05 ,, | 1,705 | 0 | 0 |
| ‡Bismuth (metal and ore) .. | 28·85 ,, | 3,394 | 0 | 0 |
| ‡Chrome Ore ... ... ... | 3,285·35 ,, | 11,827 | 0 | 0 |
| *Coal ... ... ... ... | 5,507,497·00 ,, | 1,668,911 | 3 | 7 |
| ‡Cobalt ... ... ... ... | 143·25 ,, | 1,590 | 0 | 0 |
| *Coke ... ... ... ... | 126,213·00 ,, | 109,620 | 2 | 6 |
| ‡§Copper ... ... ... | Ingots, 5,622·30 ,, value, £395,103. Matte and Ore, 1,470·15 tons, value, £32,933. | 428,036 | 0 | 0 |
| ‡Fireclay ... ... ... | 29·70 tons | 109 | 0 | 0 |
| *Gold ... ... ... ... | 345,640 ounces | 1,194,521 | 0 | 0 |
| ‡Lead ... ... ... ... | Carbonate, 1,811·00 tons | 60,888 | 0 | 0 |
| | Matte, 1,513·10 ,, | 21,113 | 0 | 0 |
| | Chloride, 78·00 ,, | 4,499 | 0 | 0 |
| | Pig, 3,085·40 ,, | 49,300 | 0 | 0 |
| *Opal ... ... ... ... | ..................................... | 80,000 | 0 | 0 |
| ‡Oxide of Iron (flux) ... ... | 313·50 tons | 686 | 0 | 0 |
| ‡Silver, Silver-Lead, and Ore.. | Ingots, 774,203 ounces | 90,243 | 0 | 0 |
| | Silver-Lead, 17,928·30 tons | 358,012 | 0 | 0 |
| | Ore, 420,909·55 ,, | 2,155,862 | 0 | 0 |
| *Shale ... ... ... ... | 22,862·00 ,, | 20,651 | 13 | 0 |
| ‡Tin ... ... ... ... | Ingots, 901·25 ,, | 120,032 | 0 | 0 |
| | Ore & Regulus, 15·10 ,, | 900 | 0 | 0 |
| ‡Tungsten Ores (Wolfram and Scheelite) ... ... ... | 49·65 ,, | 1,913 | 0 | 0 |
| ‡Zinc concentrates ... ... | 20,269·05 ,, | 44,187 | 0 | 0 |
| ‡Sundry minerals and ores ... | ..................................... | 5,412 | 0 | 0 |
| | Total.........................£ | 6,439,156 | 19 | 1 |

* Total products, including exports. ‡ Total exports only.
§ Does not include copper from imported ores smelted in New South Wales.

The above return is incomplete, particulars in regard to Platinum, Ironstone flux, Iron made from scrap, Limestone flux, and Diamonds not being yet to hand.

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Sydney : William Applegate Gullick, Government Printer.—1901.